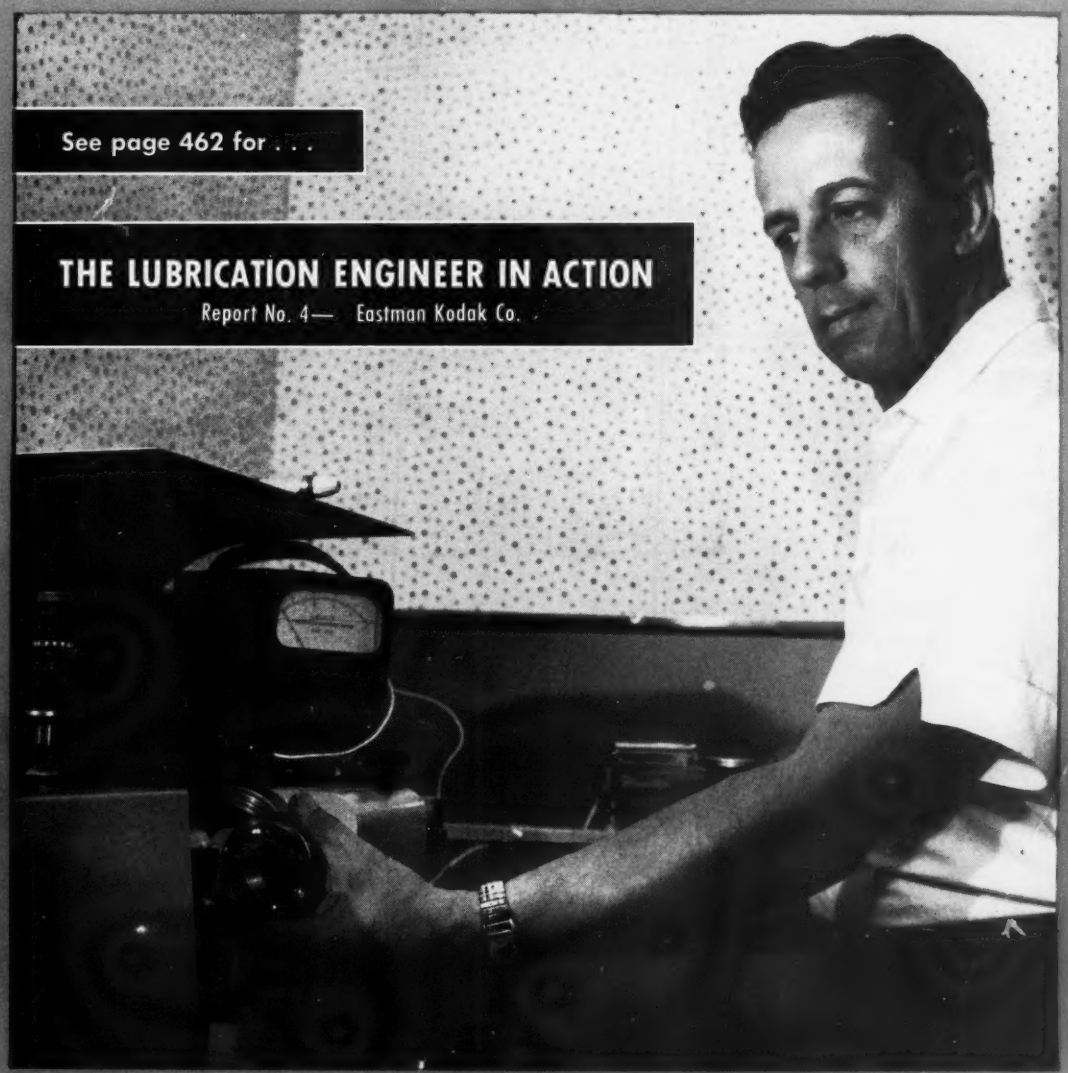
Vol. 16, No. 10 October, 1960

LUBRICATION ENGINEERING

DESIGN RESEARCH APPLICATION EDUCATION MAINTENANCE



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October, 1960

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Volume 16, No. 10
October, 1960

Lubrication Engineering

DESIGN RESEARCH APPLICATION EDUCATION MAINTENANCE

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AMOCO CHEMICALS—A NEW RESOURCE

Five AMOCO Additive Product Bulletins to help you

Here are five informative bulletins that give technical data helpful in evaluating AMOCO Additives. Bulletins document with test data and comparative illustrations, the performance of motor oils and gasolines containing AMOCO Additives. Typical physical and chemical properties of the additives are included. Technical service by experienced petroleum additive engineers, to assist you in the use of AMOCO Additives, is also available.

AMOCO 193 INHIBITOR

Gives information on this multi-functional zinc dithiophosphate motor oil additive which inhibits oil oxidation, protects bearings from corrosion, and prevents excessive wear of critical engine parts.

AMOCO 200 SERIES DETERGENT-INHIBITOR ADDITIVES

Data are given on the use of a number of the outstanding detergent-inhibitor additives of this series in making motor oils. All are combinations of Amoco's unique barium detergent and zinc dialkyl dithiophosphate inhibitor.

AMOCO 600 VISCOSITY INDEX IMPROVER

Contains data on how AMOCO 600 VI Improver helps provide easier starting, increased gasoline mileage, less ORI, greater shear stability, better oil mileage. Useful blending chart included.

AMOCO 520 SERIES METAL DEACTIVATORS

Information is provided on extending storage life of copper-contaminated gasoline stocks, heating oils and diesel fuel with metal deactivators of this series.

AMOCO 530 SERIES GASOLINE ANTIOXIDANTS

Each of the three major chemical types of gasoline antioxidants, for economical protection from gum formation, are included in the AMOCO 530 Series. Here are data on all of them.

AMOCO CHEMICALS CORPORATION
910 S. Michigan Avenue, Chicago 80, Illinois

PRODUCT BULLETIN
AMOCO CHEMICALS CORPORATION
AMOCO 193 Inhibitor
A Dialkyl
Zinc Dithiophosphate
PRODUCT BULLETIN
AMOCO CHEMICALS CORPORATION
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AMOCO 530 Series
Antioxidants
The most economical and effective protection from gum formation is available in the AMOCO 530 series antioxidants. The group consists of four products — AMOCO 531, 532, 533, 534 — and includes each of the major chemical types of gasoline antioxidants. From this AMOCO series, it is possible to select the proper treatment for each gasoline blend. Early addition to unstable streams saves antioxidant.
AMOCO 531 Antioxidant
N-Butyl-p-aminophenol in isopropanol
AMOCO 532 Antioxidant

LUBRICATION IN THE NEWS

The Society will not be responsible for the accuracy of statements made in this column. Any reference to proprietary products does not imply an endorsement of such products by the Society.

TECHNICAL PAPERS ON LUBRICATION INCLUDED IN PROGRAM AT IRON AND STEEL ENGINEERS EXPOSITION

Listed below are selected abstracts from the 45 technical papers presented in Cleveland during the four days of Iron and Steel Engineers Convention, September 27 through September 30.

Grease on Tap, by Charles A. Bailey, Lubrication Engineer, National Tube Div., and Donald R. McCaa, Product Manager, Standard Products Dept., American Bridge Div., United States Steel Corp., Pittsburgh, Pa.

Bulk grease handling is the result of improvements in the lubricants, methods of application, and containers made available to steel mills. Now the industry is ready, to make grease a mill utility-item. Methods, practices, and container designs, aimed at this end are presented to show how every mill can have grease on tap.

A Standardized Method for Rating Roller Bearing Load-Capacity, by E. C. Denne, Jr., Assistant Chief Engineer, SKF Industries, Inc., Philadelphia, Pa.

Individual bearing manufacturers have developed and applied their own methods of rating bearings. As a result, users have been confused by marked differences in the capacities claimed by various companies for the same type and size of bearing.

In an attempt to eliminate this confusion, the writer's company has published a method of rating bearings based on years of testing and study. This method is discussed in plain language with emphasis on the variables that affect bearing ratings and the importance of each to the overall rating. This "erector set" of rating knowledge will permit the user to check and compare bearing ratings on the same basis.

Test Stand Evaluation of Oil Film Roll Neck Bearings, by Norman A. Wilson, Manager of Research, and Samuel S. Rickley, Chief Engineer, Morgoil Bearing Dept., Morgan Construction Co., Worcester, Mass.

This paper discusses the design and results of three test machines. Two were simple test machines which were used to evaluate a new seal design. They are described and the results reported.

The main portion of the paper deals with the design, instrumentation, and preliminary results of a test machine built by the Aluminum Company of America in conjunction with the author's company.

This machine was designed to test a full size oil-film bearing of the size that would be used, for example, on a small cold mill or a rod mill finishing train. The mounting and loading of the bearing is similar in nature to that encountered in a rolling mill.

The test machine is in operation at the present time testing bearings at speeds up to 1200 rpm and at loads up to 130 per cent of bearing rating. Instrumentation is such that recorded data includes load, speed, oil temperature, oil flow, skin temperature of bushing, and torque.

The performance report includes operating performance of different bearing metals and designs, and attempts to compare test results of a rolling mill oil-film bearing with some of the theories developed by various engineers and scientists using smaller machines.

Oil Must Lubricate on Antifriction Backup Roll Bearings, by C. W. Southerington, Chief Engineer, Dallas Div., Revere Copper and Brass, Inc., Chicago, Ill.

Five years' experience with the installation, maintenance and use of oil mist lubricators on three 4-high mills used for cold rundown and finishing of aluminum is discussed in detail.

The general arrangement section drawing demonstrates bearing arrangement and provisions for use of oil mist passages to effect condensation of the oil, venting of air and maintenance of the oil level. Schematic arrangement of lubricators and piping considerations are discussed as well as protective controls for the system.

The annual consumption of oil on one 35 in. and one 45 in. mill has not exceeded 55 gallons between the two mills. The paper discusses experience with regard to oil specifications, maintenance, air requirements, training of personnel, cost of repairs and results of bearing inspections.

(Source: Association of Iron and Steel Engineers)

INTERMETALLIC COMPOUNDS TESTED FOR ULTRA HIGH TEMPERATURE USE

In high temperature tests of 35 intermetallic compounds, 19 test samples showed enough resistance to oxidation to be potentially suitable for structural service at temperatures up to 2300°F, according to a metallurgical survey conducted for the Air Force.

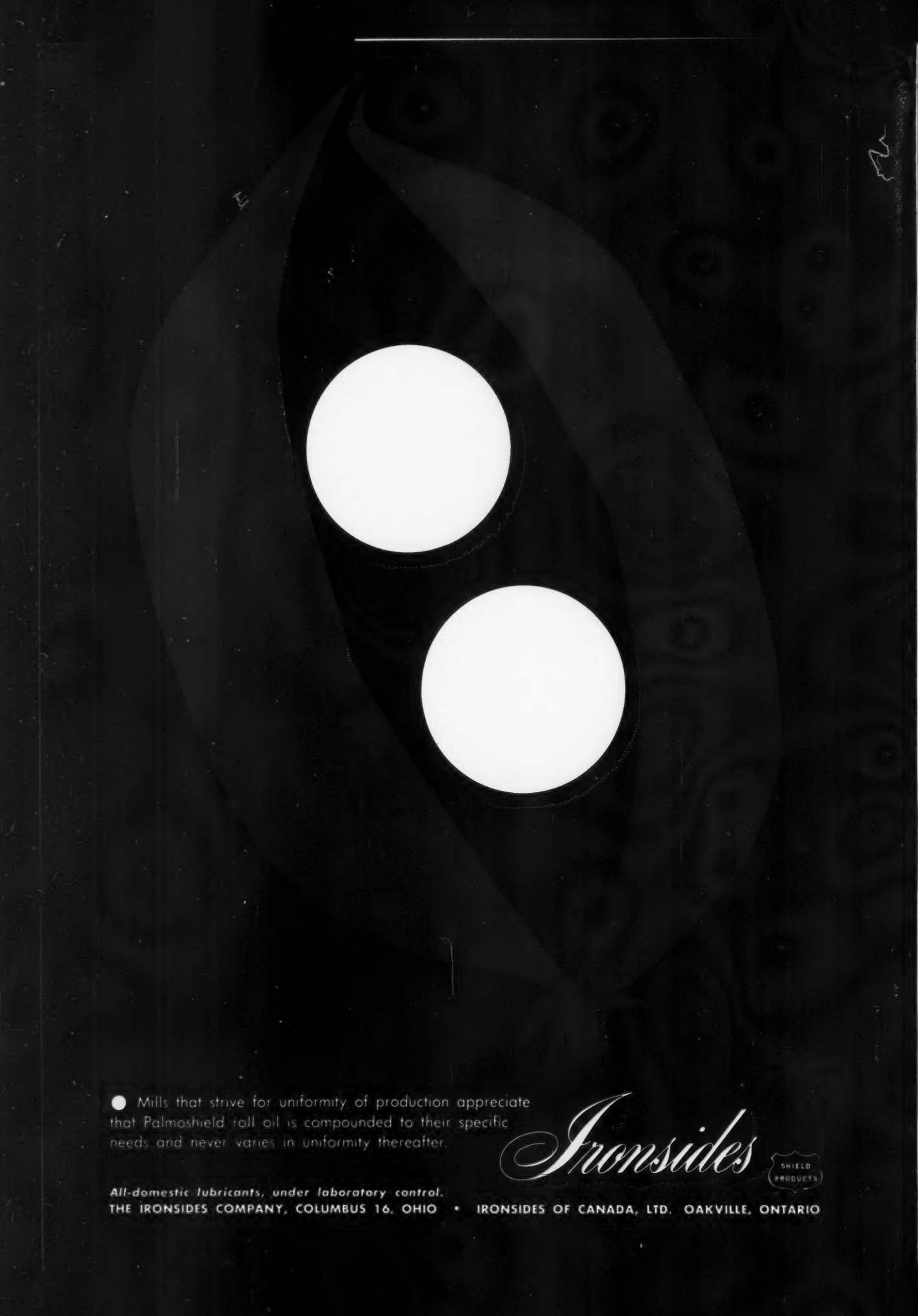
Also available from OTS are a study on the influence of heat on the creep rupture properties of three heat-resistant alloys, and a report on the effect of high energy fuel containing boron on the stress-rupture behavior of statically stressed high temperature alloys. The two publications are:

An Investigation of Intermetallic Compounds for Very High Temperature Applications. R. M. Paine and others, Brush Beryllium Company for Wright Air Development Division, U.S. Air Force. Jan. 1960. 247 pages. (Order PB 161 683 from OTS, U.S. Department of Commerce, Washington 25, D.C., $3.50.) Intermetallic compounds from 35 binary metallic systems were tested for oxidation resistance in dry air at 2300°F. Only high-melting (above 2550°F) compounds were evaluated. Test samples included aluminides, beryllides, silicides, germanides, zirconides, and a number of miscellaneous compounds. Of the 35 compounds tested, 19 showed sufficient oxidation resistance to be potentially suitable for structural service in air temperature up to 2300°F. The report includes 31 tables and 603 references, plus discussions of the test samples and test results.

Studies of Heat-Resistant Alloys. A. P. Coldren and others, University of Michigan Research Institute for Wright Air Development Division, U.S. Air Force. Feb. 1960. 108 pages. (Order PB 161 667 from OTS, U.S. Department of Commerce, Washington 25, D.C., $2.50.) Three metallic substances were evaluated as part of an Air Force study to overcome air and space vehicle design restrictions caused by creep rupture properties of heat-resistant alloys under production conditions.

(Source: U.S. Department of Commerce, Washington, D.C.)

(*Continued on page* 445)



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LUBE IN THE NEWS

(*Continued from page* 443)

SKF TO SET U.S. SUBMARINES' 'SILENT' BEARING TEST LEVELS

An electronic check on noise measuring devices will be run by SKF Industries to aid the Navy obtain the quietest bearings made in the U. S.

"Quiet-running rolling bearings—used in many applications on nuclear powered submarines—are a critical need if American submarines are to escape unfriendly sonar detection," said Thomas W. Morrison, SKF director of engineering and research, in announcing the ball and roller bearing firm's recently awarded contract.

The SKF checking system was developed to uniformly set test equipment sensitively examining the noise-producing vibration levels of the products of six competing U. S. bearing makers supplying the Navy. It is reported that the same calibration procedure will also be made for equipment at the Navy's Engineering Experiment Station, Annapolis, Md.

Navy bearing suppliers will ship their test equipment to SKF's laboratory and the calibration work is expected to be completed within 18 months. (Source: SKF Industries, Inc.)

LUBRICATION OF INSTRUMENT MOTORS SUBJECT OF HOLTZER-CABOT SYMPOSIUM DURING ISA SHOW WEEK

"Lubrication of Instrument Motors" was the subject of the Third Annual Instrument Motor Symposium sponsored by the Holtzer-Cabot Motor Division of National Pneumatic Co., Inc. in New York on Tuesday evening, September 27, during the week of the ISA Conference and Exhibit.

As the operating requirements of instrument motors become more severe, new lubricants and new methods of lubrication must keep pace. The Symposium will cover this subject with talks by a panel of six experts, each one a specialist in a particular area of motor lubrication. These are to be: Chart Drive Motors, Daystrom, Inc., Weston Instrument Div.; Balancing Motors, Hays Corp.; Ball Bearings, New Departure Division, GMC; Sleeve Bearings, Amplex Div., Chrysler Corp.; Petroleum Lubricants, Esso Standard Oil Co.; Synthetic Lubricants, E. F. Houghton & Co. (Source: Holtzer-Cabot Motor Division of National Pneumatic Co.)

AIR FORCE AWARDS LUBRICANT RESEARCH CONTRACT

The United States Air Force has awarded a new Research and Development contract to E. F. Houghton and Co., Philadelphia, Pa. for development work leading to new fire-resistant lubricants and fluids to be used in high speed aero-space vehicles where temperatures are too high for conventional fluids.

This contract is under the direction of the Nonmetallic Materials Lab., Materials Central, Wright Air Development Division. It represents an extension of the Air Force program to provide materials for efficient performance of new space vehicles. (Source: E. F. Houghton and Co.)

THE BRITISH HYDROMECHANICS RESEARCH ASSOCIATION TO HOLD INTERNATIONAL MEETING ON FLUID SEALING

On April 17, 18, and 19, 1961, the British Hydromechanics Research Association is planning to hold an international meeting on Fluid Sealing. Papers on recent technical advances in fluid sealing will be presented and opportunities will be provided for discussion between workers in this and related fields. Topics include: *Liquid Seals* (Rotating Shafts —Reciprocating Shafts); *Gas Seals; Sealing Materials* and a miscellaneous category.

The Research Association is welcoming contributors and the subject matter will be left to the author as long as each paper will make a fundamental contribution to the theory of sealing or a related topic. Inquiries should be addressed to: H. Stephens, Information Officer, The British Hydromechanics Research Association, South Road, Temple Fields, Harlow, Essex, England. (Source: The British Hydromechanics Research Association)

FLUID POWER SOCIETY HOLDS ANNUAL MEETING

Frank L. Mackin, Chairman of Engineering Shops, General Motors Institute, has been selected to head up the Fluid Power Society, a new technical organization serving the hydraulic and pneumatic transmission fields.

Chicago has been chosen as the location for the first Annual Meeting of the Society, which will be held on October 19, 1960, the day before the Sixteenth National Conference on Industrial Hydraulics in the same city.

Other officers of the Society are: President—Frank L. Mackin (Chairman of Engineering Shops, General Motors Institute, Flint, Michigan), Vice President — Walter Ernst (Vice President and Director of Engineering, Commonwealth Engineering Company, Dayton, Ohio), Treasurer—Allan E. Morris (Editor, Hydraulics and Pneumatics Magazine, Cleveland, Ohio), Executive Vice President and Secretary—Barrett Rogers (Executive Vice President and Secretary, National Fluid Power Association, Milwaukee, Wisconsin).

The Board of Directors consists of the above named officers and: George Altland (Supervisor, Hydraulics School, Vickers, Inc., Detroit, Michigan) and Lynn L. Charlson (President, Char-Lynn Company, Minneapolis, Minnesota). (Source: Fluid Power Society).

(*Continued on page* 492)

INDUSTRY NOTES

Minature Precision Bearings, Inc. announced the acquisition of Carter Engineering Company, Ferrysburg, Michigan, manufacturers of the patented "Alinabal" series of rod-ends, spherical bearings and ball linkage devices.

M.P.B.I.'s Split Ballbearing Division manufactures and markets a line of specialty ballbearings for materials handling, agricultural machinery, industrial machine tools, and other applications.

Plans to build a large new engine-testing laboratory as part of an accelerated program to develop fuels and lubricants for engines of the future have been announced by Socony Mobil Oil Co.

The new facility, to be built at the company's research laboratories in Paulsboro, N.J., will accommodate up to 20 test engines, ranging from giant marine and railway diesels to gas turbines, truck and passenger car engines.

According to an announcement by Parker-Hannifin Corp., Duper Dynamics Inc., Hayward, California, has been established as a distributor for Parker industrial tube and hose fittings, hydraulic accumulators, check valves, relief valves and general-purpose lever control valves, Crown air system regulator-filter-lubricators, and Hannifin pneumatic and hydraulic cylinders and air control valves.

Better Greases Through BAROID RESEARCH

BARAGEL 24* provides greater stability in greases made from non-petroleum oils

BARAGEL 24, a non-soap grease-gelling agent, gives greater stability to greases made from such non-petroleum oils as polyalkylene glycols, di-2-ethylhexyl sebacate, di-2-ethylhexyl adipate and castor oil. The development of BARAGEL 24 is another result of Baroid Chemicals' research.

Greases compounded with BARAGEL 24 are subjected to the most rigid testing. One of these tests measures grease penetration over the range of unworked to 10,000 strokes. In non-petroleum based oils, BARAGEL 24 produces greases that are exceptionally stable to working in the ASTM grease worker. These greases show minimum breakdown under the most rigorous operating conditions.

BARAGEL 24 is a reaction product of organic ammonium halides and refined sodium montmorillonite. BARAGEL 24 is a member of the BARAGEL-BENTONE* family of products which has been used so successfully in greases, plastics, paints, inks and other fields.

*Trademark of National Lead Company for an organic ammonium montmorillonite

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BAROID CHEMICALS, INC.

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SECTION NEWS

Chicago—The monthly meeting which will be held October 20 at the Builders Club, 228 No. LaSalle will feature refreshments at 6:30 p.m. with the Business Meeting at 8:00 p.m., followed by a technical presentation by Allen Berchler, Lubrizol Corp., Cleveland, Ohio. His subject will be: "Testing Formula for Motor Oil — API + AMA = MS."

New York—The New York Section is sponsoring a six-week educational course, which began October 4, 1960. The course will be held in the Public Service Building, Newark, N.J. from 7:00 p.m. to 9:00 p.m.

The schedule is as follows:

Oct. 4—"Lubrication Fundamentals" —Speaker: R. G. Cunningham, Shell Oil Co.

Oct. 11—"Properties of Lubricants"—Speakers: R. McKay and Dr. Stan Pier, Products Development Lab., Cities Service

Oct. 18—"Hydraulics"—Speaker: K. G. Henrikson, Mobil Oil Co.

Oct. 25—"Metal Working"—Speaker: Arnold Ackerman, Anderson Oil Co.

Nov. 1—"Bearings"—Speakers: T. A. Eddy, American Brake Shoe Co., and C. R. Gillette, New Departure Div. of General Motors Corp.

Nov. 15 — Panel — Moderator: J. J. O'Connor, Editor Power Magazine, McGraw Hill; Panel Members: Plant Lubrication—W. E. Sauerbrun (Chief Lubrication Engineer, U. S. Rubber Co.), W. P. Rapp (Manager Mechanical Division, National Biscuit Co.), H. D. Lewis (Consolidated Edison Co.); Industrial Oil—G. E. Kellis (Sinclair Oil Co.); Industrial Grease—John Feltman (Sealol, Inc.); Bearings — L. E. Hoyer (American Brake Shoe Co.).

Syracuse—Section secretary, Dick Stimer, has arranged the first three fall meetings as a series, having to do with Metal Working—all three of which are part of a Metal Working Seminar. These meetings will be at the Yates Hotel as follows:

FIRST MEETING—September 19, 1960
Will be held in conjunction with the local Chapter of S.A.E.
Speaker: Robert Gibbons, Chief Metallurgical Engr., Bendix Corporation, Utica, New York
Topic: "Machinability versus Micro Structure" — Illustrated talk with slides

SECOND MEETING—October 17, 1960
Speaker: George Vosmer, Manager Coolant Division, Cincinnati Milling Machine Company
Topic: "Machining Fluids and their Application"—This talk will be accompanied by motion picture and slides

THIRD MEETING—November 21, 1960
Speaker: John Boyd, Director of Metal Working Fluids, Quaker Chemical Company
Topic: "Grinding Fluids and their Application"

Rochester—The first meeting of the new season was held September 14 at Maplewood Inn with the Business Meeting at 8:00 p.m. following a social and dinner hour. Mr. Nicholas Walton, Special Products Division, Garlock, Inc., with a background in the field of bearings, presented an interesting and informative talk on "Metal Backed Teflon Bearings." The Rochester program schedule for the 1960-1961 season is as follows:

September 14—"Metal Backed Teflon Bearings"—Nicholas Walton, Garlock Inc.

October 12—"Industrial Oil Filtration"—John R. McCoy, Indiana Commercial Filters Corporation

November 9—"Rust Prevention"—Jack Di Piazza, Esso Standard Oil Company

January 12—(Joint Meeting with ASME) "Sports Car Racing and Engineering"—Bill Milliken, Cornell Aeronautical Flight Research

February 8 — "Oil Reclamation" — M. A. Pratt, New Departure Bearings

March 8—Short talk about ASLE followed by talk on "Worm Gear Lubrication"—L. O. Witzenburg, ASLE President, Cleveland Worm & Gear

April 12—"Lubrication of Earth Moving Equipment"—Nevin T. Brenner, Gulf Oil Corporation

May 10—"2-Cycle Engines"—Joseph Budd, Homelite Corporation

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UCON heat-transfer fluids do not ordinarily sludge, coke, or gum after months of use at temperatures as high as 450-500°F. Thus, electric immersion heaters and other heat-transfer surfaces stay clean and give long, continuous operation.

UCON heat-transfer fluids have good viscosity stability and low pour points. These properties permit operation over wide temperature ranges yet eliminate cold weather problems and the need for auxiliary heating equipment.

UCON fluids and lubricants also give top performance as:

- Rubber and textile lubricants
- Hydraulic fluids
- Cosmetic components
- Anti-foam agents
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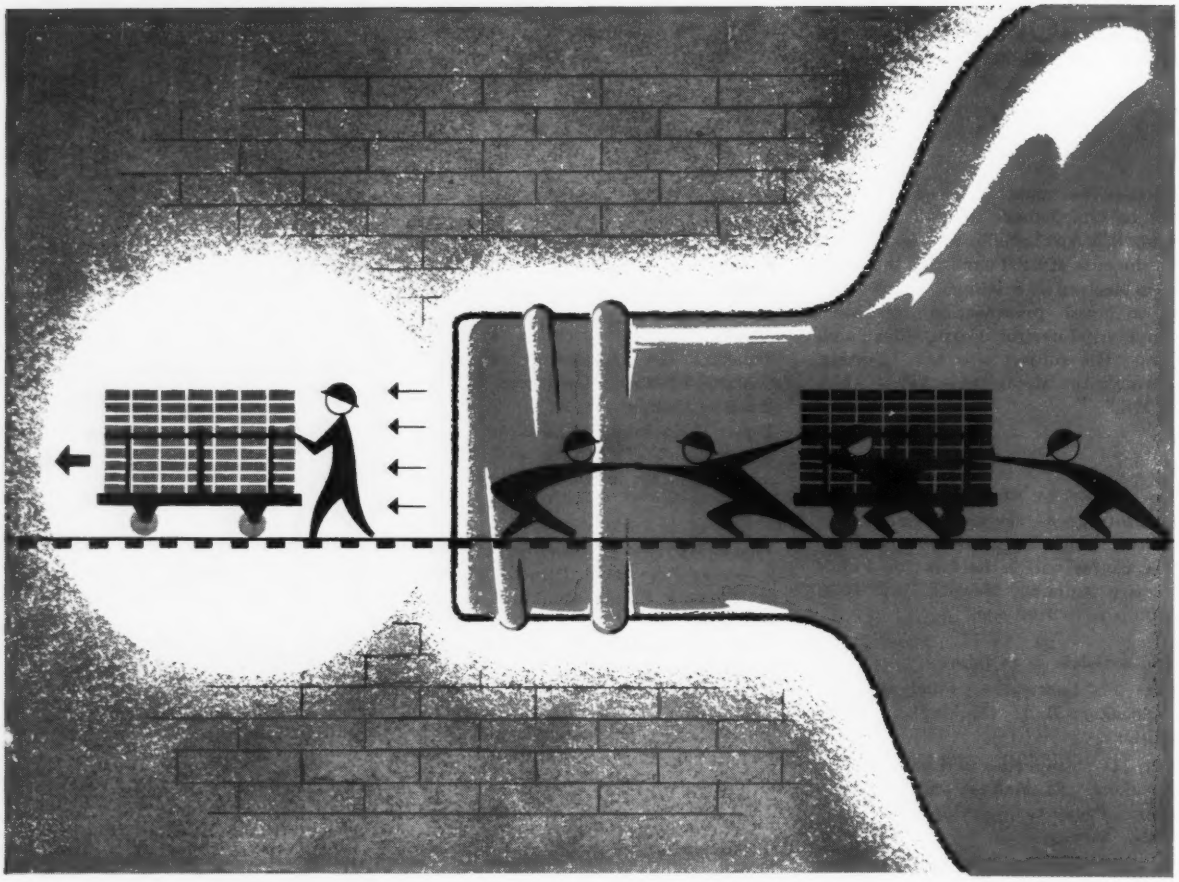


New "hot" grease ends brick-oven bottlenecks

. . . and one man outperforms four!

Ceramic Combustion & Engineering Company, consultants for the Davidson Brick Co., Los Angeles, California, ran into production bottlenecks while using ordinary grease in dryer-car bearings. Oven temperatures (350° to 400° F.) cooked the grease solid . . . stalled the cars loaded with bricks in the dryer. Bearings seized so badly that four men were needed to move each carload.

Now—with Shell Darina Grease 2 as the lubricant, Davidson reports: "Bearings roll free, even at 400° F., one man, instead of the four previously required, can *easily* roll a carload of bricks . . . no more bottlenecks caused by frozen bearings."

Darina® Grease 2 is an economical, multi-purpose grease with exceptional stability in high-temperature applications. It offers these outstanding qualities:

HIGH-TEMPERATURE PERFORMANCE. *100° F. better* than conventional multi-purpose greases.

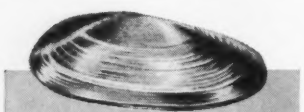
EFFICIENT SEALING. Contains no soap —nothing to melt and run out.

HIGH RESISTANCE TO WATER WASH-OUT. Doesn't dissolve or separate when mixed with water . . . lubricates efficiently under wet conditions.

POSITIVE RUST PROTECTION. Protects bearings even under severe moisture conditions.

ECONOMICAL. Savings up to 35% in grease and labor costs alone are possible because of Darina's superior performance over a wide range of plant operating conditions.

For more information on Darina Grease, write: Shell Oil Company, 50 West 50th St., New York 20, N. Y., or 100 Bush St., San Francisco 6, California. In Canada: Shell Oil Company of Canada, Limited, 505 University Avenue, Toronto 2, Ontario.



An Interesting Fact! Every Shell Branded Industrial Lubricant is named for a sea shell. Shown here: Darina solenoides.

SHELL DARINA GREASE

the multi-purpose, high-temperature grease

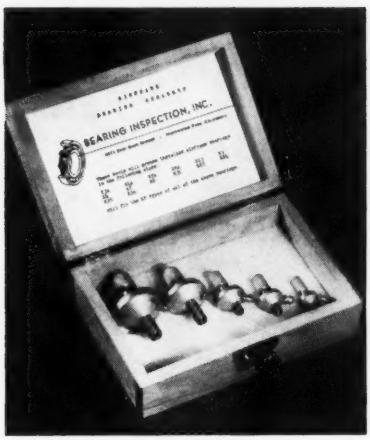
SHELL

NEW PRODUCTS

NEW BEARING CLEANING AND GREASING TOOLS MANUFACTURED

The Greasing and Cleaning of ball and roller bearings is simplified by a new tool designed by Bearing Inspection, Inc. This tool will be useful in all industries that use and maintain bearings.

The solvent flushing, and/or relubrication of a ball or roller bearing —even the cleaning and lubrication of shielded bearings—can be accomplished quickly and easily.



The Cleaning and Greasing Tools have no moving parts to be maintained or wear out, giving them an unlimited service life. Sets of tools can be furnished to fit most all size ranges required. Model AF-14 consists of five pieces to service bearings ranging from ⅝" to 1⅜" outside diameter.

Circle No. 1 on Reader Service Card

36-STATION VOTATOR FILLER FOR LUBE OILS INTRODUCED

Introduction of a new Votator rotary piston filler that is said to fill up to 800 quart containers of lubricating oil per minute was announced by Girdler Process Equipment Division of Chemetron Corporation, Louisville.

Girdler Process Equipment Division states that the new Votator P36L is engineered for proper synchronization with associated equipment in continuous, automatic packaging lines handling lubricating oils, upper cylinder and friction-proofing lubricants, brake fluids, and radiator flushes.

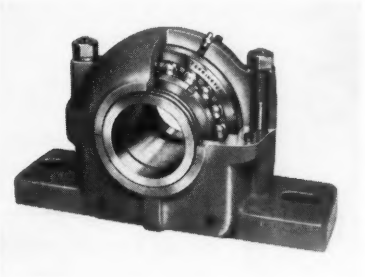
A feature of the 36-station filler is a "magnetic monitor" device on Votator rotary piston units, providing positive control to prevent jammed valves and eliminate resultant downtime, repair costs and replacement of parts.

Circle No. 2 on Reader Service Card

SPHERICAL ROLLER BEARING PILLOW BLOCKS ANNOUNCED

New heavy duty pillow blocks, with self-aligning spherical roller bearings in split housings, are available in 143 sizes from The Torrington Company.

Two heavy duty series are offered —Series SAF, with two bolts clamping cap to base, and Series SDAF, with heavier castings and four cap bolts. All sizes are available with straight bore bearings for shouldered shaft mounting or with adapter bearings suitable for mounting on straight commercial shafting.



Housing seats are machined to bearing widths plus ⅜", permitting each Torrington pillow block to be used as a floating unit or, with standard ⅜" wide stabilizing ring in place, as a fixed pillow block.

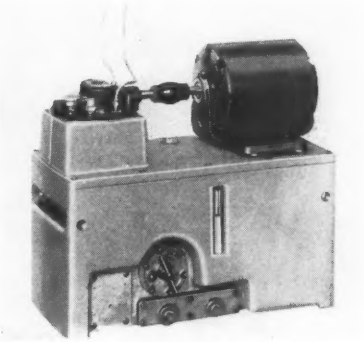
The Torrington spherical roller bearings used in the new pillow blocks have high radial and thrust load capacities combined with low torque. The internal self-aligning feature of the bearing permits a reasonable latitude in alignment of pillow blocks during installation and operation. An integral guide flange, adding strength to the bearing inner ring, guides the rollers and prevents roller skew.

Circle No. 3 on Reader Service Card

CIRCULATING LUBRICATION SYSTEM WITH AUTOMATIC RATE CONTROL DEVELOPED

An automatic lubricating system, designed to circulate clean, filtered lubricant through machine bearings at controlled rates, has been developed by Bijur Lubricating Corp.

Called "Circulube," this system provides machine builders with a means of centralizing automatic lubrication which both controls oil circulation through machine bearings and allows for its re-use.



The Circulube system consists of a Lubricator, a distribution system, and the Control-Units which determine flow of oil to bearings. An additional special feature of the system is a Pressure Signal Switch which prevents machine operation until proper oil pressure has been developed.

Circle No. 4 on Reader Service Card

ROLLING OIL BASE DEVELOPED TO REDUCED COLD STRIP ROLLING POWER

Reduction of power requirements, cleaner strip, and elimination of cleaning prior to annealing are all claimed for a new rolling oil base developed by Baker/Gubbins Company, Detroit.

The product conditions the steel surface, increases corrosion protection and is said to prevent scratching and scuffing when applied at the pickler oiler.

The compound, (No. 717), can be diluted with mineral oil to form a stable oil, or may be mixed with hot water to form a metastable emulsion.

Circle No. 5 on Reader Service Card

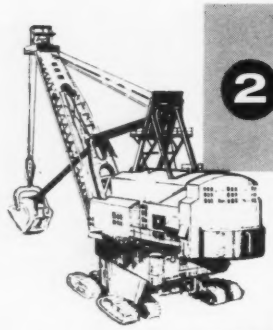
(*Continued on page* 451)

NEW... for heavy industry

EP Vetura A

MULTI-PURPOSE LUBRICANT

1. NO MELTING POINT
2. SPECIAL EXTREME PRESSURE EXCEEDS MINIMUM 45 POUND TIMKEN O. K. LOAD RATING
3. RESISTANT TO WATER
4. OXIDATION INHIBITED
5. SHEAR STABLE



EXTENDS EFFECTIVE LUBRICATION

UNLIMITED APPLICATION

920 SPRUCE STREET

SAHARA OIL COMPANY

ST. LOUIS 2, MISSOURI

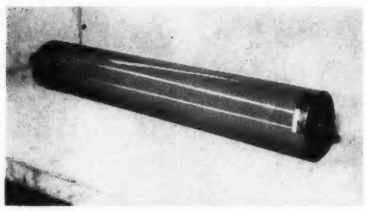
SPECIFICATIONS	EP Vetura A MULTI-PURPOSE LUBRICANT
Worked Penetration @ 77° F.	310-340
Timken O. K. Load, Minimum	45 lbs.
Pressure Bleed Test, Per Cent Maximum	5.0
Shear Stability	Excellent
Water Resistance	Excellent
Norma Hoffmann Oxidation Stability, 100 hrs. @ 210° F.	5 lb. Max. Drop
Wheel Bearing Test	Pass
Rust Protection	Pass
Texture	Buttery
Color	Amber
Drop Point, °F.	None
Mineral Oil Specifications:	
Viscosity @ 210° F.	60-70
Viscosity @ 100° F.	450-650
Flash, °F., Minimum	425
Color, Maximum	5

NEW PRODUCTS

(*Continued from page* 449)

LEAKPROOF ACCUMULATORS INTRODUCED

Hydrodyne Industries, Inc. announces the introduction of a complete line of leakproof hydraulic piston accumulators for use in the following industries: aircraft, automotive, automation, ground support, missiles, marine, mining, road machinery, farm machinery, foundries, machine tools, injection molding machines, hydraulic presses, power packs, oil industry, chemical processing plant, paper mills, and wherever fluid power is used.



The free piston contains three "O" rings—all of which are active in the system. An automatic check valve arrangement dispenses with pressure build-up between "O" rings. The manufacturer claims that the accumulator is leakproof because of this basic design and it carefully maintains quality control of close tolerances. The standard operating pressure is 3,000 psi covering the range of 19 cu. in. to 23 gallons; temperatures −40°F to 200° F.

Circle No. 6 on Reader Service Card

IMPROVED PERMAWICK DEVELOPED FOR EXTREME OPERATING CONDITIONS

A new Special grade of Permawick self-wicking lubricant for bearings operating in extreme conditions is announced by the Permawick Company, and its licensee, Wesco Manufacturing Company.

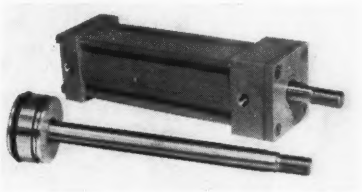
The new "Permawick-280" is developed with a new extreme pressure additive, formulated specifically for bearing use and is recommended for applications involving high or low temperatures; marginal and boundary lubrication, and high thrust loadings for vertical shaft positions.

Circle No. 7 on Reader Service Card

NEW LOW COST MO-BAR AIR AND LOW PRESSURE HYDRAULIC CYLINDERS

A new line of low cost air and low pressure hydraulic cylinders, from 1⅛" to 3½" bore, has been announced by Bo-Mar Hydraulics Co.

The new Mo-Bar "COST SAVER" cylinders enable fluid power users to achieve substantial cost savings when they are used for both original equipment or replacement purposes.



Of simplified design, the Mo-Bar "COST SAVER" air and hydraulic cylinders features include one-piece aluminum piston; hard chrome plated piston rod; aluminum end caps; seamless brass tube; block vee seals and wiper on rod and piston; and with adjustable cushions either end.

Available in flush, foot, front and rear flange, clevis or pivot mountings, the new Mo-Bar "COST SAVER" air and hydraulic cylinders are said to be both versatile and dependable on all fluid power applications.

Mo-Bar Bulletin No. 205 with detailed description, together with complete measurements for all bores, is available.

Circle No. 8 on Reader Service Card

CAST IRON MACHINING COMPOUND DEVELOPED

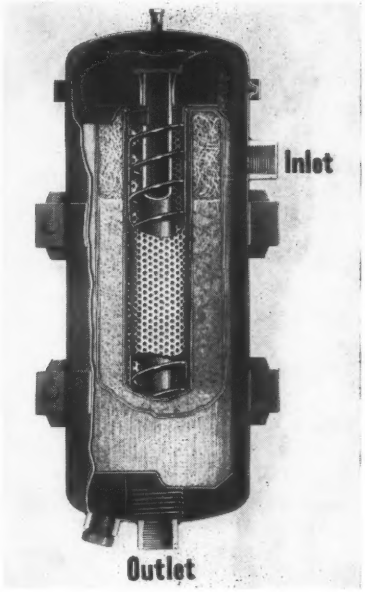
Baker/Gubbins Co. has formulated a compound known as No. 588 for cast and malleable iron machining operations employing central coolant systems. It is offered to prevent build-up of hard deposits on the machines, in the lines and throughout the system; keep chucks clean, stop rust of chips, parts and tooling; and also prevent chips or turnings from matting or forming a cake.

No. 588 reportedly reduces oil and water content of the chips and, in shops with captive foundries has reduced the melting loss in the cupola by cutting chimney losses from 40% to only 3%. The product also possesses high film strength at very low concentrations, and has low bacteria growth.

Circle No. 9 on Reader Service Card

NEW FULL-FLOW FILTER MANUFACTURED

A new large single element full-flow CP filter based on Winslow's patented principle of having two flow rates in one element has been developed. It requires only one inlet and one outlet, minimizing installation costs and time.



The single element contains two filtering media—fine and superfine—encased in a double cotton cover, eliminating any danger of separation. It filters the full-flow oil stream at a reported flow rate of up to 25 gallons per minute of hot engine oil (S.A.E. 30) with a pressure loss of only approximately 4 psi.

Circle No. 10 on Reader Service Card

HIGH TEMPERATURE LUBRICANT OFFERED

Product Techniques, Inc. has developed a high temperature lubricant suitable for journal bearings or sliding friction at temperatures from −65° F to 1100° F. Designated as PT-605, the product is a grease consistency suspension of Molybdenum Disulphide and other lubricating solids in an extreme temperature fluid.

The manufacturer states that the parts to be coated with PT-605 should be thoroughly cleaned and be free from rust or oxides. The lubricant can be applied through conventional grease guns for field application.

Circle No. 11 on Reader Service Card

(*Continued on page* 453)

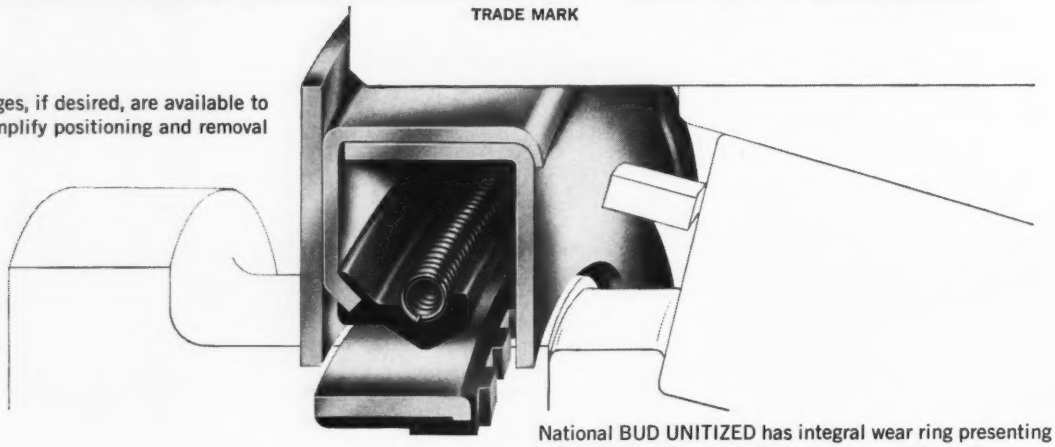
NATIONAL® OIL SEAL LOGBOOK

Presenting!

NATIONAL BUD UNITIZED

TRADE MARK

Flanges, if desired, are available to simplify positioning and removal



National BUD UNITIZED has integral wear ring presenting rubber surface to shaft. Wear ring turns with shaft, sealing lip is never exposed to damage, cannot score shaft.

A new unitized oil-seal-and-wear ring that eliminates:

SHAFT WEAR OR SCORING

SEPARATE METAL WEAR SLEEVES

EXPENSIVE SHAFT FINISHES

COSTLY SHAFT RE-MACHINING

SEALING LIP INSTALLATION DAMAGE

SPECIAL INSTALLATION PROCEDURES

New National BUD UNITIZED seals are now in production, in a limited range of sizes, for heavy oil and grease sealing applications — including truck, bus and tractor uses. Still newer BUD UNITIZED seals are on the way for higher speed automotive and similar uses.

Changing a National BUD UNITIZED oil seal automatically changes the wear sleeve — in one fast, simple operation. Since the seal has its own integral wear ring, it is almost impossible to install it other than squarely on the shaft. Expensive shaft finishing is no longer a necessity, nor is leakage under a metal wear ring a problem — both thanks to the rubber surface BUD UNITIZED presents to the shaft.

For complete details or skilled engineering help on application of BUD UNITIZED seals, write direct, or call your National Seal Applications Engineer. You'll find him in the Yellow Pages, under Oil Seals.

NATIONAL SEAL

Division, Federal-Mogul-Bower Bearings, Inc.
General Offices: Redwood City, California
Plants: Van Wert, Ohio, Redwood City and Downey, California

6013-R

NEW PRODUCTS

(*Continued from page* 451)

NEW SELF-DRAIN FILTER ADDED TO CROWN LINE

A Crown compressed air line filter with a new integral self-draining feature has been added to the Crown line of Filters, Regulators and Lubricators manufactured by Hannifin Company, a division of Parker-Hannifin Corporation. Offered in ½" through 1" pipe sizes, these new units employ the basic parts of the standard Crown Filters with the addition of a reportedly fool-proof drain valve, linkage and float mounted on a removable plug which screws into the bottom of a new cast aluminum bowl.

The float and linkage are designed to open the drain valve when liquid level in the bowl reaches a pre-determined height, then closes the valve when the float drops to a "low" point during discharge of the liquid. A small quantity of liquid is always present in the bowl during and after the draining sequence providing a "water seal" which prevents air leakage through the drain valve.

A sump is provided in a plug to collect and remove solids from the bottom of the bowl. The drain valve can also be removed for inspection and cleaning.

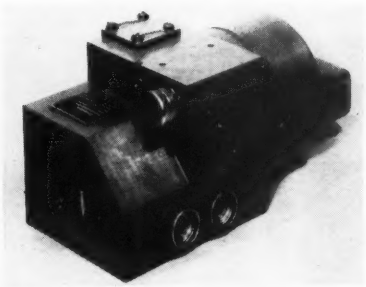
Circle No. 12 on Reader Service Card

A NEW LINE OF ELECTRO-HYDRAULIC SERVO VALVES INTRODUCED

A new line of electro-hydraulic servo valves designed to control hydraulic power or flow in response to electrical signals has been introduced by Consolidated Controls Corporation.

The use of a sensitive pilot valve to obtain hydraulic amplification within the valve body eliminates the necessity for external electronic or electrical amplification of control signals; full flow may be obtained with signal power as low as two milliwatts.

In operation, the electrical signal is applied to a dry torque motor, which, in turn positions a pilot spool



valve. The spool valve opens ports which admit hydraulic fluid under pressure to position the main output spool valve which actually controls flow of the fluid. Mechanical feedback from the main valve to the torque motor in a direction opposite to the electrical signal sets up a force balance to maintain the valve in the position indicated by the electrical signal.

Valves designed for operating pressures from 150 to 4,500 pounds per square inch and with full flows ranging from 0.5 to 50 gallons a minute with a 1,000 psi pressure drop are available. Output flow may be linear or shaped to desired curves.

The units are designed for operation with all hydraulic system fluids and most fuels. Moth media and ambient temperatures may be anywhere in the range from −65 to 450°F.

Circle No. 13 on Reader Service Card

STOCK TEFLON AVAILABLE

Fluoro-Plastics, Inc., is processing a complete line of TEFLON basic (tape, sheet, rod, tube) shapes and specializes in large size molding. Sheet up to 48" square, tube up to 36" diameter, and rod up to 20" diameter are processed as well as large intricate shapes of TEFLON.

New literature containing tables and descriptive matter on chemical, electrical, and mechanical properties of TEFLON has been published. A stock list with standard dimensions and a tabulation of weights and tolerances is also included.

Circle No. 14 on Reader Service Card

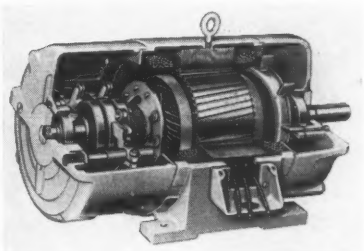
NEW LUBRICANT DEVELOPED

Lloyds Laboratories of America has developed an anti-rust, anti-corrosive, penetrating lubricant called MOOVIT, which is useful for garages, fleets, machine shops, construction companies, and industrial plants. Non-flammable, non-toxic, MOOVIT has been found to be harmless to the skin. In addition to serving as an anti-rust and cutting lubricant, MOOVIT is offered to remove rust on chrome and prevent recurrence and is available in ½ pints to 55 gallon drums.

Circle No. 15 on Reader Service Card

REDESIGNED WOUND ROTOR MOTORS ANNOUNCED

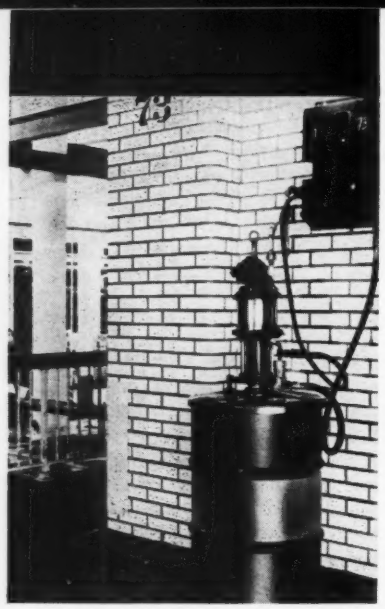
The Louis Allis Co. has announced the ava'lability of a new line of completely redesigned Wound Rotor Motors to meet NEMA Standards in frame sizes 213 to 326 U.



The new design features reductions in both size and weight while retaining durable cast iron housing and end bracket construction with oversize grease reservoirs for maximum protection against shock, corrosion, and insuring minimum maintenance. The rotor is precision wound and has both ends dynamically balanced for quiet, vibrationless operation. Rotor end coils are banded with an epoxy fiberglas to form a bond to prevent end coil shorts due to wire cutting insulation.

These motors are suited for elevators, cranes, hoists, printing presses, etc. They can be furnished with open, drip-proof or totally enclosed, non-ventilated enclosures for horizontal, ceiling or side-wall mounting.

Circle No. 16 on Reader Service Card



From this central supply and control, pure lubricants are pressure-fed through sealed lines to injectors that deliver the right amount of lubricant at the right time to hundreds of lubrication points.

LINCOLN

Centralized Lubrication helps move Budweiser bottles by the millions

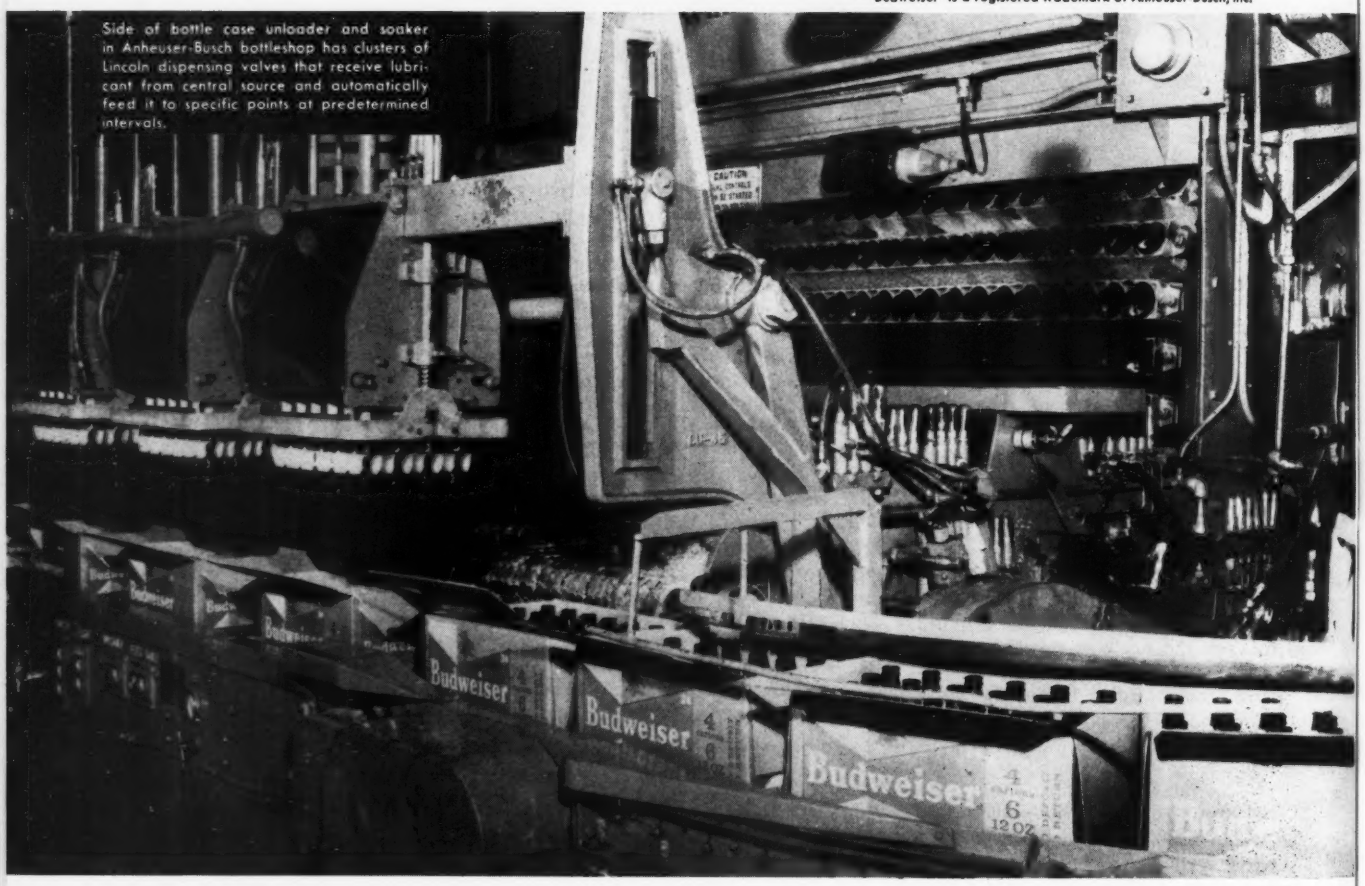
Millions of Budweiser* bottles pass through the soakers and sterilizers at Anheuser-Busch's St. Louis brewery—largest in the world. The hundreds of bearings in this automatic process must be correctly lubricated to keep a constant supply of containers moving in for refill.

Lincoln's Centralized Lubricating System looks after this job automatically, eliminating waste of manpower and lubricants, costly downtime, mechanical damage, and physical danger that threatens wherever machines are still oiled by hand.

Anheuser-Busch has used Lincoln systems for more than 20 years . . . another reason why *Lincoln is known by the companies it keeps.*

For information that can help you maintain high-speed production schedules in your plant, write today for complimentary copies of Catalog 81 and Lincoln's new centralized lubrication brochure, "A Report to Management."

*"Budweiser" is a registered trademark of Anheuser-Busch, Inc.



Side of bottle case unloader and soaker in Anheuser-Busch bottleshop has clusters of Lincoln dispensing valves that receive lubricant from central source and automatically feed it to specific points at predetermined intervals.

6040

LINCOLN ENGINEERING COMPANY

DIVISION OF THE McNEIL MACHINE & ENGINEERING CO., 4010 GOODFELLOW BLVD., ST. LOUIS 20, MO.

PRODUCT LITERATURE

NEW CHEMICAL PACKING

A recent DuPont developed TEFLON fiber as a corrosive resistant is being braided into a mechanical packing by the Flexrock Company. The TEFLON fibers are braided over a braided glass fiber core and impregnated with TEFLON. This construction is designed to present a soft, pliable, low friction packing for use on centrifugal as well as reciprocating and static applications.

A catalog containing construction and application information on this as well as many other TEFLON mechanical packing is available. Also included is case histories on applications that have been greatly improved by the use of Flexrock 405.

Circle No. 17 on Reader Service Card

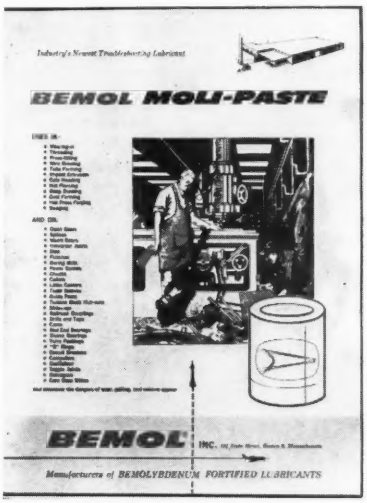
THERMOPLASTIC BALL VALVES DESCRIBED IN BULLETIN

New top-entry, top-adjusting thermoplastic ball valves made of UPVC (unplasticized polyvinyl chloride) or "Penton" chlorinated polyether are described in bulletin TTP-180, "Ball Valves for Corrosive Service," available from Tube Turns Plastics Inc.

The bulletin describes the new line's corrosion-resistance characteristics and on-the-line maintenance features and gives dimensions for threaded, socket and flanged-end type valves in ½" through 2" nominal pipe sizes.

Circle No. 18 on Reader Service Card

REPORT ON MOLI-PASTE LUBRICANT PUBLISHED



Bemol, Inc., manufacturer of Bemolybdenum lubricants has released a report on its product, Moli-Paste. In addition to giving the specifications of the two types of Moli-Paste lubricant available, the report gives the advantages of Moli-Paste along with the illustrations of typical applications.

Circle No. 19 on Reader Service Card

BULLETIN ON JET GAS BURNERS NOW AVAILABLE

A six-page bulletin describing two types of precision-jet gas burners has been published by The Barber Manufacturing Company, Cleveland. The free literature lists the BTU specifications and physical dimensions of 24 models of the company's impinged jet type and 24 models of the slotted cap jet design. The data sheet presents the information in easy-to-read tabulated form.

Circle No. 20 on Reader Service Card

NEW DATA SHEET AVAILABLE

A new data sheet No. 6007 giving complete dimensional and performance specifications for miniature extended inner ring ball bearings is now available.

Circle No. 21 on Reader Service Card

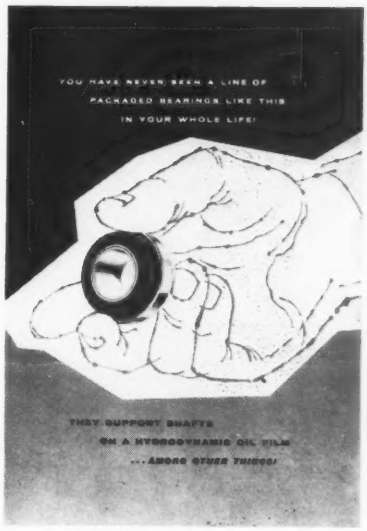
GEAR AND SPEED REDUCER CATALOG ANNOUNCED

Publication of a new 246-page gear and speed reducer catalog has been announced by the Ohio Gear Company. The fully illustrated book contains information on sizes, ratings and specifications of the company's complete line of gears and speed reducers. Also contained are easy to understand engineering data on the proper selection of gears and reducers to meet specific job requirements.

Circle No. 22 on Reader Service Card

UNIQUE BEARINGS DESCRIBED IN BROCHURE

A four-page brochure, illustrated with 12 charts and diagrams, describes revolutionary "Hy-Film" line of packaged bearings which run on hydrodynamic oil films.


YOU HAVE NEVER SEEN A LINE OF
PACKAGED BEARINGS LIKE THIS
IN YOUR WHOLE LIFE!
THEY SUPPORT SHAFTS
ON A HYDRODYNAMIC OIL FILM

Nine graphs and charts give complete operating characteristics of bearings and tell how to compute life at various speeds and temperatures. Charts also show the amount of torque consumed and the horsepower loss at different speeds and temperatures. The brochure also describes unique electron bearing analyzer used to test bearings and compute bearing characteristics.

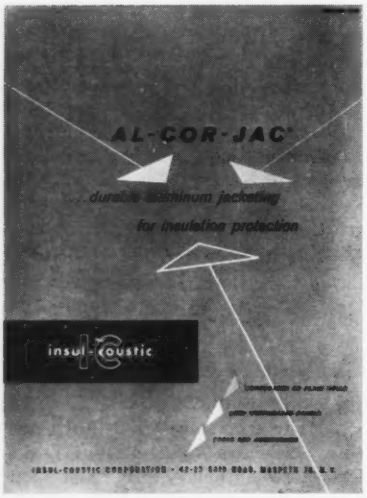
Circle No. 23 on Reader Service Card

(*Continued on page* 456)

PRODUCT LITERATURE

(*Continued from page 455*)

NEW BULLETIN ICB DESCRIBES INSUL-COUSTIC ALUMINUM JACKETING



The new four-page Insul-Coustic Bulletin ICB describes the company's Al-Cor-Jac and their complete line of aluminum products for protecting insulation on piping, tanks or towers. Photos of typical installations are included. Also included is a brief summary of other insulation accessory products manufactured by Insul-Coustic.

Circle No. 24 on Reader Service Card

BOOKLET PUBLISHED ON SOLID LUBRICANTS

The theory and practice of lubrication by solids are the primary subjects in a new booklet published by The Alpha-Molykote Corporation, manufacturer of molybdenum disulfide lubricants for industry. The booklet discusses boundary friction and the role of solid lubricants to reduce friction and wear under heavy loads and at high temperatures.

The 24-page, 4-color booklet describes the major advantages of molybdenum disulfide solid lubricants—low coefficient of friction, natural affinity for adherence to metal surfaces, and pressure resistance beyond the yield point of any metal. The company's research facilities and activities, both in this country and in Germany, are also described.

Circle No. 25 on Reader Service Card

DATA BULLETINS PUBLISHED ON SPOOL TYPE 4-WAY HYDRAULIC VALVES

Two new data bulletins on small, spool type 4-way hydraulic valves that provide 11 flow patterns, have just been published by Sarasota Precision Products, Inc., of Sarasota, Florida.

The free literature features flow-pressure characteristics, dimensions, approved J.I.C. symbols and flow patterns. These data bulletins also contain weight, material and porting specifications.

Circle No. 26 on Reader Service Card

ELECTRONIC SELECT-A-SPEDE DRIVE BULLETIN RELEASED

The Louis Allis Co., Milwaukee, recently released Bulletin #101 that describes the operation and performance of The Louis Allis Electronic Select-A- Spede Drives.

These drives range in size from ¾ HP to 4 HP, and feature a D.C. Motor powered from a compact, wall mounted Electronic Control Panel, which is controlled by an operator's Control Station. Adjustable voltage is applied to the motor armature from the Electronic Control Panel which converts the a.c. line voltage to a regulated rectified d.c. source.

Circle No. 27 on Reader Service Card

TECHNICAL BULLETIN DESCRIBES INSTRUMENTATION SYSTEMS FOR JET ENGINE TEST FACILITIES

Gilmore Technical Bulletin TD-100, describing some typical instrumentation systems for jet engine test facilities, has just been released by Gilmore Industries, Inc. Data released was derived from the several hundred systems installed by Gilmore for the Navy and Air Force in their jet engine, rocket engine, and missile thrust measurement systems.

Gilmore systems measure such engine variables as thrust, fuel and water flows, temperature, pressure, speed and oil consumption.

Circle No. 28 on Reader Service Card

mbi
ON GUARD SINCE 1888

LUBRICATING GREASES
METAL WORKING LUBRICANTS
SPECIAL PROCESS OILS

BEMOL ®

BEMOLYBDENUM FORTIFIED LUBRICANTS

"Never Underestimate the Importance of Lubrication"

Consult Our Lubrication Engineers

MAGIE BROTHERS OIL COMPANY

Franklin Park, Illinois Chicago Phone TUxedo 9-4800

25 x 25 on

MORGOIL BEARINGS

We mean a coil of aluminum foil 25 *hundred thousandths of an inch* thick and 25 *miles* long. High quality coils of this size are routine production on this Four High MORGOIL equipped foil mill at Anaconda Aluminum Company, Louisville, Kentucky.

MORGAN CONSTRUCTION CO., WORCESTER, MASSACHUSETTS

ROLLING MILLS • MORGOIL BEARINGS • GAS PRODUCERS
WIRE MILLS • EJECTORS • REGENERATIVE FURNACE CONTROL

MB 37

New, important

AKRA-EZ TEST KIT for lubrication engineers

NOW YOU CAN MAKE A COMPLETE OIL ANALYSIS IN 12 MINUTES

Test oil in actual service whenever you think it is necessary, quickly, accurately, without waiting for a laboratory test report. This AKRA-EZ Oil Test Kit saves oil and provides guaranteed protection of expensive equipment—pays for itself in a short time.

Simple test procedures show visually the oil viscosity through a range from 50 to 400 SSU. For plotting, ASTM viscosity charts are furnished.

Simple hand sling centrifuge and magnetic device determines degree of contamination of water and/or metal particles and/or insoluble solids.

A new simplified AKRA-EZ method determines the acidity (oxidation) of oil and provides a method for visually determining when acidity is detrimental to machine operation.

Protect your position—guarantee your authority with an AKRA-EZ Oil Test Kit. It prevents premature oil changing—prevents use of contaminated, harmful oil—avoids equipment failure by assuring you that all lubrication or hydraulic oil used is giving maximum protection to your valuable equipment.

Easy-to-use kit has complete directions. Includes neutralization number, viscosity magnetic carrying bar and other test devices . . . includes centrifuge, thermometer, sample bottles, syringe and a comprehensive Manual with charts. The complete kit comes in a sturdy, luggage type carrying case.

Order today! AKRA-EZ Oil Test Kit is sold on a money-back guarantee for only . . . $98.00 F.O.B. Anaheim, Calif.

MANUAL: Included with your kit is a two-part comprehensive manual which is probably the most complete text book about hydraulic and lubrication oil testing ever compiled for men in plant and equipment operation. The first section is devoted to (1) theory of why oil breaks down, (2) importance of viscosity, acidity, heat, contamination, etc., (3) importance of filters, (4) discusses types of filters, etc. The second section explains how to make optimum use of the kit. All is presented with numerous photos and includes a complete set of charts. Value $5.00.

R & W ENGINEERING SERVICE CO.

2118 CRIS AVENUE • ANAHEIM, CALIF.

BOOK REVIEW

"Friction and Wear," Edited by Robert Davies, Elsevier Publishing Company, Amsterdam, 1959

This book represents the proceedings of a Symposium on friction and wear held by the General Motors Research Laboratories at the GM Technical Center near Detroit, Michigan in June 1957. The following papers, and in some instances, extended discussions thereof, are included in these proceedings.

"*A Tentative Model for the Mechanical Wear Process*," by Robert Davies

"*Energy Losses of Balls Rolling on Plates*," by Richard C. Drutowski

"*Some Metallurgical Aspects of Friction and Wear*," by L. F. Coffin, Jr.

"*The Seizure of Metal Pairs during Boundary Lubrication*," by C. L. Goodzeit

"*Recent Experimental Studies of Solid Friction*," by F. P. Bowden

"*Friction, Durability and Wettability Properties of Monomolecular Films on Solids*," by W. A. Zisman

"*A Study of the Stick-slip Process*," by E. Rabinowicz

"*Cohesion between Two Oriented Single Crystals of Copper*," by Allan T. Gwathmey and Lawrence D. Dyer

One of the objectives of the Symposium was to encourage free interchange of information by those in attendance at the Symposium. Approximately 125 leading scientists from Universities and from Industrial, Government, and Independent Research Laboratories were present; backgrounds of those in attendance covered a number of scientific disciplines including solid state physics, surface chemistry, mechanics, and metallurgy.

In general, the book is felt, by this reviewer, to be a valuable contribution in the field and a worthwhile addition to the scientist's library.

(Reviewed by Edmund E. Bisson, National Aeronautics and Space Administration)

PERSONALS

Nelson R. Droulard of Gwynedd Valley, Pa., formerly Research and Development Director of Budd Company's automotive division, has been named Technical Director of Mechanical and Nuclear Engineering at Franklin Institute Laboratories, Philadelphia.

Mr. Droulard succeeds Mr. Francis L. Jackson who in January became Assistant Director of the Laboratories. He will direct three Laboratories' branches; Engineering Mechanics, Friction and Lubrication, and Heat Transfer and Fluid Flow.

Elwin E. Smith has been appointed general sales manager of Climax Molybdenum Company, a division of American Metal Climax, Inc. Mr. Smith joined Climax Molybdenum Company in 1955 as manager of lubricant development. He previously had served as manager of chemical sales, a post he held for two years.

ELWIN E. SMITH

Jack R. Reinsma has been appointed manager of product programs of the Alemite and Instrument Division of Stewart-Warner Corporation. In his new position, Mr. Reinsma will direct development, refinement and improvement of all product lines of the division.

Douglas D. Brien has been named President of the Ohio Gear Company, manufacturers of stock and special gears and speed reducers. Mr. Brien's appointment culminates 14 years of service with Ohio Gear. He has served as Executive Vice President since 1949.

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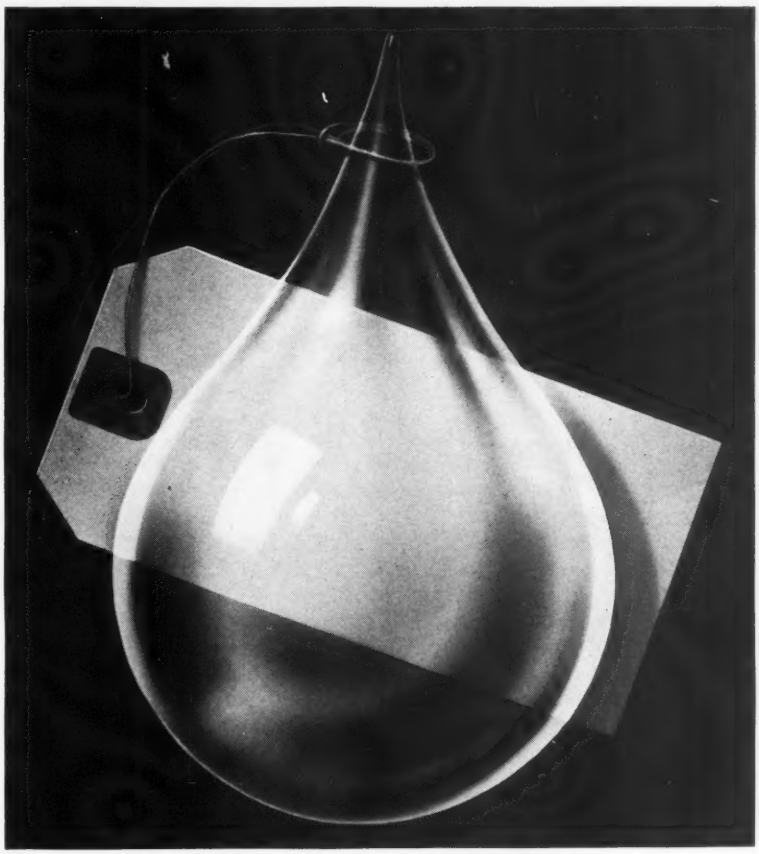

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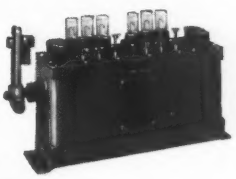

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Vol. 16, No. 10

Lubrication Engineering

Castro's Achilles' Heel

A few weeks ago, I spent an evening with a well-informed engineer from Cuba. He mentioned many things that have not appeared in our newspapers—things which prove that Castro and his bearded cutthroat lieutenants were educated in Moscow and are now following a planned program directed and ordered by Moscow.

When I was in Cuba a year ago, the hotels which normally catered to American tourists were almost empty. Today, they are filled with Spanish speaking Russians and Chinese. Obviously, these men have had years of training, not necessarily to be sent to Cuba—but their masters knew Communism would eventually gain a foothold in one Latin American country—and Cuba happened to be the first.

When Castro took over, he had the backing of a vast majority of Cubans, including all the poor people to whom he promised a vastly improved standard of living. Today, he is favored by only a small minority, for almost everyone is worse off. For instance, those who made less than two-thousand dollars per year paid practically no taxes—now they are taxed fifteen per cent on the first dollar they earn. Their bellies are emptier, their liberties are even more curtailed, and they would like to cut Castro's throat—but he has 150-thousand men with rifles. No one can even speak out against Castro without landing in jail.

Those Cubans who do not have a Castro rifle are wondering if he has a weak spot—an Achilles' heel. When he nationalized the refineries, they had hope that the country would be paralyzed through lack of gasoline, because his supplies of crude were cut off by the Free World. But when Moscow told him it was time to seize the refineries, they had tankers already on the open seas, and within a few days the refineries had plenty of crude.

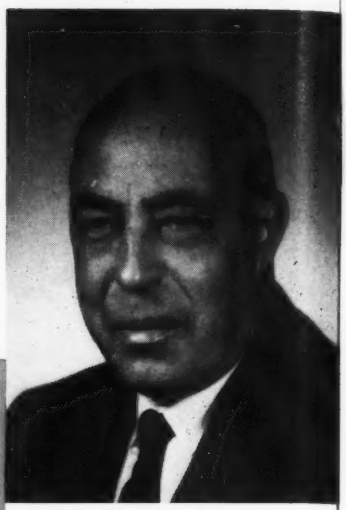
But there is one hope. Cuba has very limited facilities for making lubricating oils and greases. And, at this time, it appears that most of the Communist countries have the same problem. They have no surplus lubricating oil or grease to give Castro.

Castro's regime is well aware of this weakness. They have attempted to standardize on only four lubricating oils—four grades and types of oil to lubricate everything from sewing machines to sugar mills. So, perhaps there is hope that the machines which are necessary to keep Cuba's economy at a level to insure Castro's continuing existence will wear themselves into the junk pile just because they cannot be properly lubricated.

Did you ever stop to think what would happen to any country's industry if there were no lubricating oil or grease? It could be a powerful "Achilles' heel".

L. O. Witzenburg
President, ASLE

The Lubrication Engineer in Action



CHARLES L. POPE

Report No. 4—
CHARLES L. POPE
at Eastman Kodak Co.
Rochester, N.Y.

Born into one of America's pioneer families in engineering, (remember the old Pope Hartford car and the Jenny, circa 1918), "Charlie" Pope cut his technical teeth earlier than most. When the other kids had sling shots, he was playing with an end wrench and the stains on his pants were grease instead of grass. But even with such a head start, he didn't waste any time in settling down to the job that has become his lifetime career—and resulted in significant contributions to the science of lubrication engineering.
Charlie joined Eastman Kodak in 1930 as an industrial engineer at the company's Kodak Park Works Plant. He set to work organizing the company's lubrication program on a plant-wide basis. Today, he's still hard at it, driving to and from work almost every day in a fine old 1939 Rolls Royce. And from the looks of things, both Charlie and the Rolls are getting stronger as the years go by.

Imagine a factory full of complex special production machinery where a number of departments operate continuously, 24 hours a day, 7 days a week *in total darkness!* Next, impose cleanliness requirements so rigid that lubricants must be applied in *drops or cubic centimeters.* Then establish a schedule calling for lubrication at regular intervals of a *year or more*—and make it work!

Such a situation actually does exist at Kodak Park Works in Rochester, New York. In addition to the normal run of lubrication requirements, it typifies the sort of problem that makes the lubrication engineering operation unusual and stimulating. Needless to say, it's a successful operation, often spectacularly so.

For instance, some time ago, it became necessary to increase speeds and pressures on the calendar roll stacks in one of the company's paper mills. If new drives were specified to provide the higher speeds and pressures it was estimated that a costly expenditure would be involved.

Consulted on the project in connection with lubrication requirements and possible problems, Charles L. Pope and his lubrication engineering staff suggested changes in bearing design and a special lubrication system instead of new drives. As a result, the necessary speed and pressure increases were achieved at a fraction of the previously estimated cost. And in addition, the first few months of operation indicated that annual power and operating costs would actually be reduced in spite of the increased operating speed.

This story illustrates two important aspects of lubrication engineering at Kodak. First, the lubrication

engineer and his staff work on a consulting basis, available to all departments and divisions in connection with lubrication problems. Second, lubrication engineering at Kodak approaches every problem from two sides, studying the mechanical aspects of the situation as well as seeking the lubricant that will work best.

This insistence on "seeking the cause as well as the cure" when lubrication problems arise has led to deep involvement in basic design and specification of bearings and drives in addition to concern with the materials normally within the lubrication engineer's province. It makes lubrication engineering at Kodak quite unusual in the extent to which it is considered important by all divisions of management in all phases of plant operation.

But it was not always thus. In 1930, when the program was started 576 different oils and greases were being specified, procured and used. Lubrication problems were handled on a divisional basis. A subsequent industrial engineering survey indicated that a plant wide approach would be desirable in the interest of both operating efficiency and economy.

With management approval, Charlie tackled the job and suddenly become a lubrication engineer, incidentally, one of the first. But, lest the impression be given that such a challenge was easily or quickly met, it must be pointed out that a long missionary period was just beginning when Pope first got the go-ahead to see what he could do about improving lubrication practices.

Complete and detailed surveys of lubrication requirements in all parts of the plant had to be made. Then comparative evaluations of all materials in use or available were necessary. This in turn required testing equipment and laboratory facilities. It took time, lots of long range management confidence and, above all, wholehearted cooperation from the operating and maintenance people.

Steady progress was made over the years and the lubrication engineering operation as it now exists is indicative of what time, confidence and cooperation, plus a good engineer, can do in any organization, large or small.

The most obvious accomplishment has been a drastic reduction in the variety of lubricants in use. Today, only 12 different oils and 3 different greases are specified. This simplification is even more striking in light of the size and scope of the production operation. More than 20,000 people are employed at Kodak Park in various plants covering an area of more than 1,000 acres. Activities ranging from film paper and chemical making using high speed production equipment to automatic packaging and precision machining, power generation and waste disposal.

Operating pressures encountered vary from near absolute vacuum to 30,000 psi; temperatures run from —80 to 900 F; speeds range up to 90,000 rpm and bearing loads go as high as 70,000 pounds. Still only 12 oils and 3 greases cover well over 99 percent of all requirements.

Naturally, a few very special lubricants are necessary for certain applications (some of them experimental), but these amount to less than 100 pounds annually. And to keep a close watch on these "specials", their procurement and application are reviewed frequently lest lubricant inventories begin to grow complex and cumbersome again.

Another aspect of this careful watch on the materials required and their application is significant economy in the consumption of lubricants. Although the plant has nearly tripled in size since the lubrication engineering program was initiated, lubricant expenditures have decreased every year!

However, the really outstanding achievements of the lubrication engineers at Kodak Park have been in reducing maintenance costs and minimizing the loss of production time for routine maintenance. It is estimated that scheduled maintenance affected by lubrication has been reduced by as much as 60 to 70 percent. At the same time, unscheduled shutdowns or bearing failures due to lubrication have been virtually eliminated.

To illustrate the magnitude of such savings, before Pope and his crew proved that it was unnecessary to do so, every electric motor in a large operating division was completely dismantled for cleaning and lubrication every 6 months. Now, these tear downs are scheduled at intervals of 10 years or more.

In another case, 2,000 man hours were required to disassemble, clean and reinstall the bearings of a paper mill each year. After extensive experimentation with solvents and methods, the lubrication engineers devised a procedure for cleaning and flushing all bearings in place. Disassembly was eliminated and the downtime for bearing cleaning was reduced to less than two days.

Striving for results like these, trying to make bearings last longer with less attention, led naturally to careful study of the bearings themselves. Fundamentally, no lubricant known can make a defective, inferior or overloaded bearing stand up.

Bearing technician checks physical quality of ball bearings on noise testing equipment. This test includes listening to bearing sound as an indication of quality.

Thus, bearings as well as lubricants have become the special concern of the Kodak lubrication engineering staff. This concern extends from consultation on original design and specification to cleaning and reworking and includes testing of all new bearings. The extreme importance attached to this phase of the lubrication engineering program is indicated by the bearing testing program.

All incoming new bearings are individually inspected under the supervision of the lubrication engineers before they are cleared for installation. The inspection is carried out in a carefully soundproofed room. As the bearing is run under standard conditions, its "song" is amplified and analyzed by specially trained technicians to detect physical defects. Perfect bearings eliminate a troublesome uncontrolled factor in any study of lubrication efficiency and give a good lubricant a chance to do its job properly.

In addition to new bearings, all bearings removed from equipment in the course of maintenance or overhaul are sorted, graded, cleaned and subjected to inspection before being classified. After testing, two out of three of these sorted bearings are found suitable for further service.

But important as is this saving of costly bearings that would otherwise go to the scrap heap, the savings are vastly greater in production time and maintenance costs achieved by virtually eliminating bearing failure from physical defects.

Another interesting sidelight on lubrication engineering at Kodak is a significant contribution to plant safety. This comes about indirectly through planning for easier lubrication of new machines of all types.

From a lubrication engineering standpoint, the more convenient it is to lubricate a given machine, the less likely it is that some critical lubrication point will be missed or neglected. Consequently, when consulted on the design of new equipment, Charlie Pope's crew gives careful attention to such features as safety guards and drive arrangements that will have a definite effect on the accessibility of lubrication points.

Special drive guards and centralized group terminals for lubrication lines, as illustrated, are examples of the safety contributions that have resulted.

All lubricants are applied at Kodak by "service equipment men". These specially trained operators are a part of the maintenance department and are under the direction of the superintendent of maintenance.

General guidance of their work, however, comes from the lubrication engineers. Equipment is lubricated in accordance with schedules prepared by the lubrication engineers and any abnormalities or signs of trouble are promptly reported to them. Thus even though there is no direct line of *authority* from the lubrication engineer to the service equipment group that actually does the work of applying lubricants, the line of *communication* and *cooperation* is direct and efficient.

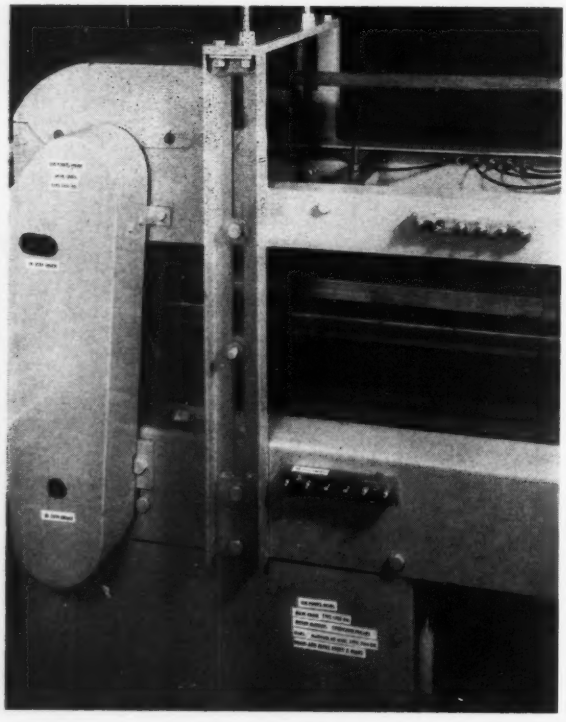
It is interesting to note here that no system of follow-up or reporting on the application of lubricants has ever been found necessary. Rather, high standards of performance are assured by having specially qualified people carrying out logical and essential assignments with an "integrity of purpose" that seems to imbue the entire Kodak organization. Equipment failure due to negligence or error in lubricant application is virtually nonexistent.

Physical handling and storage of lubricants at Kodak is a relatively minor problem. Because the emphasis is on using minimum safe quantities rather than "plenty to be sure," the most difficult aspects of storage and handling are in assuring absolute freedom from contamination and in measuring small applications accurately. In many cases, a service equipment man will make his scheduled rounds for as long as a week before refilling a grease gun. In fact, the actual job of lubrication at Kodak consists more of preventive maintenance rather than application of lubricants.

The importance of freedom from contamination is emphasized by an installation requiring the operation of approximately 12,000 ball bearings on grease applications of only 1.5 cc. each. The grease is applied by means of a graduated hypodermic syringe and the men applying it wear special lint-free coveralls. Only one bearing has failed since this system was put into operation . . . it was assembled by a worker in ordinary cotton clothing and seized up within 3 hours due to lint contamination.

Lubrication engineering with precision of this order naturally requires considerable laboratory support. In addition to the bearing lab, which is an integral part of the lubrication engineering program, two other completely equipped labs serve Pope's group.

The first of these is the Kodak industrial laboratory. As might be expected from the nature of Kodak products, it is one of the country's finest and completely set up for all standard lubricant evaluations. It is here



A section of a Kodak packaging machine shows special design features incorporated for safety reasons and ease of lubrication.

LEGEND

A. F. —ALEMITE FITTING
H. O. —HAND OILED
B. B. —BALL BEARINGS
R. B. —ROLLER BEARINGS
P. B. —PLAIN BEARINGS
M. O. L.—MAINTAIN OIL LEVEL
H. P. —HAND PACK
N. B. —NEEDLE BEARINGS
W. P. —WASTE PACKED
S. F. —SIGHT FEED OIL CUP
W. K. —WICK FEED OIL CUP
G. C. —GREASE CUP
R. O. —RING OILED
S. O. —SAIN OILED
B. H. F. —BUTTON HEAD FITTING
F. F. —FORCED FED
R. —RESERVOIR
C. —CIRCULATING

LUBRICATION SCHEDULE

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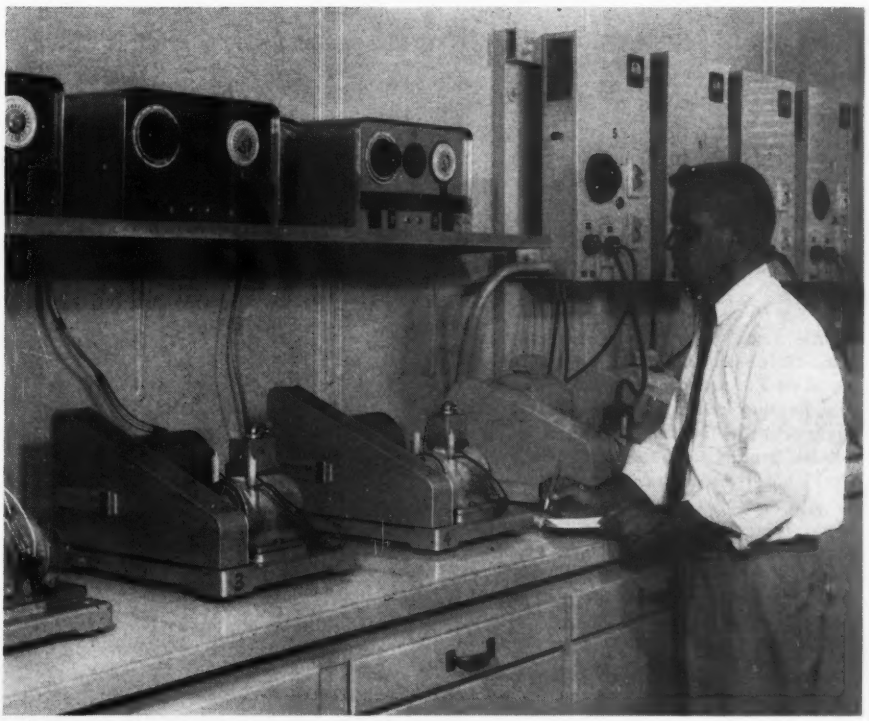
Page 1 of 1 Pages

Location on Floor	Equipment	Item No.	Parts to Be Lubricated	Type of Brgs. or Gears	Method of Lub.	E.K. Lub.	Frequency of Lub.	Frequency of Inspection	COMMENTS
	SORTER		Motor	B.B.	Plug	2028	Yearly	Weekly	Clean & repack every 6 years.
			Worm & Worm Gear	-	B.H.F.	2040	Weekly	Weekly	Keep housing filled with grease.
	CAP LINER		Motor	B.B.	Plug	2028	Yearly	Weekly	Clean & repack 6 years.
			Gear Reducer	Spur	H.O.	1600	M.O.L.	Weekly	Drain & refill 2 years.
			Variable Sheave Brgs.	P.B.	A.F.	2028	Monthly	Weekly	
			Drive Chain	Roller	Brush	2040	Monthly	Weekly	
			Open Gears	Spur	Brush	2040	Monthly	Weekly	
			Misc. Bushings	P.B.	B.H.F.	2040	2/Week	2/Week	
			Vacuum Chuck Bushing	P.B.	H.O.	1600	M.O.L.	Daily	Keep oil cup filled.
			Chuck Cam Shaft	2 P.B.	H.O.	1600	2/Week	2/Week	
			Table Ways	-	H.O.	1600	2/Week	2/Week	
			Yoke	P.B.	B.H.F.	2040	Monthly	Weekly	
			Chuck Cam	-	Brush	2040	Monthly	Weekly	
			Transfer Arms	-	H.O.	1600	Monthly	Weekly	Few drops in oil cups.
	VACUUM PUMP		Pump	2 P.B.	H.O.	1600	Weekly	Weekly	Few drops in oil cups.
	AIR LINE		Lubricator	-	-	1600	Keep Lubricator Filled		
	CONVEYOR		Drive Motor	B.B.	Plug	2040	Yearly	Weekly	Clean & repack 6 years.
			Gear Head	Worm	H.O.	1600	M.O.L.	Monthly	Drain & refill 2 years.
			Flange Cartrg. Brg.	8 B.B.	A.F.	2028	6 Months	Weekly	
			Drive Chain	Roller	Brush	2040	Monthly	Weekly	
			Oven Conveyor Chain	-	Lubricate with Silicone Oil -- As Needed.				

This is a basic lubrication schedule supplied to operating department heads at Kodak Park Works. From this schedule, a method is devised for service equipment men to follow in applying lubrication.



William Welk reads test data from an electronic timer for purposes of evaluating the life expectancy of a grease being tested in the engineering laboratory at the Kodak Park Works plant of Eastman Kodak Company, Rochester, N.Y.

that incoming materials are checked to assure conformity with specifications.

Then, when new materials are under consideration, the engineering laboratory also comes into play. This is a special facility available to the consulting engineering staff and permits comprehensive accelerated running tests on experimental lubricants to predict their actual performance under plant conditions. Along this line, the engineering laboratory includes a modern well equipped grease testing installation for evaluating greases.

Basic research into the "why's" and "how's" of lubrication are also made possible by the engineering laboratory, and the lubrication engineering budget makes provision for such work too—with good return on the investment. Projects now in work at Kodak promise new and improved solutions to certain difficult and unusual problems in both rotary sealing and dry bearing operation.

The official place of the lubrication engineering function in the Kodak organization is actually quite simple. In brief, the lubrication engineering group, now grown to 6 men since Pope started the program 30 years ago, is a part of a complete and well organized consulting engineering staff. Their field of concern is company wide and they report, through the director of engineering, to the manager of "ECM&U"—Kodak Park's contraction for combined control and coordination of engineering, construction, maintenance and utility functions.

Two amusing anecdotes demonstrate the penetration and acceptance of the lubrication engineering function throughout the plant. In the first, the power plant people were troubled with birds nesting in their coal bunkers. Guess whom they called for expert advice —Pope spent a pleasant afternoon at the zoo and came up with the answer, 1″ mesh wire screening over all openings.

In the second, a test of LPG fuels for in-plant use went awry. Contrary to Pope's predictions and assurances, a heavy, foul-smelling exhaust cloud obscured the test area within minutes after the run began. The trouble wasn't found until Charlie poked his head under the hood of the offending tractor and found a plug shorted out by a cross brace. The brace had been installed to strengthen the tractor frame when the unit was first put into service. Incidentally, LPG fuels are now extensively used at Kodak.

THE APPROACH

These anecdotes probably have their counterparts in the career of almost every lubrication engineer, and they illustrate two very basic factors in Charlie Pope's approach to his task, precepts that he has applied from the very beginning. First, come up with the answer, even if you have to go to the zoo for it—and be sure it's right. Second, when things seem to be not quite as expected, always "look under the hood".

Charlie Pope (right) discusses with members of his lubrication engineering staff the wearing characteristics of a bearing being tested on special equipment in the engineering division laboratory at the Kodak Park Works plant of Eastman Kodak Company, Rochrester, N.Y. Left to right: James John, Cort Miller, David Hall, James Halter, and Charlie Pope. Mr. Robert Torrens of the lubrication group was absent when this picture was taken.

Most of the rules that Pope works by are equally practical, even if not quite so pithy:

1. Keep up to date—ready, study, and stay in touch with other men in the field via meetings, technical associations and cooperation in special problem solving.
2. Rely on and develop good men wherever lubrication is concerned by giving them equally large portions of latitude, authority and backing.
3. Record failures and breakdowns even more carefully than successes. Herein lies the opportunity for (and the key to) further improvement.

But there is one over-riding idea that provides at once an understanding of the careful technical procedures at Kodak and explains the high degree of acceptance for lubrication engineering. It is best expressed in Charlie Pope's own words, "Know what you're doing and why—never just change oil and hope."

THE ASSIGNMENT

As a part of the consulting staff, Pope and his group are available for work on equipment design, operating or maintenance problem where lubrication or bearings are involved. As they arise, these problems are referred directly to the lubrication engineers and account for about half of their time.

The other half of the time, they are occupied with what might be termed "self-initiated" assignments. These latter, as well as the basic approach to almost every referred problem, arise in pursuit of the fundamental objectives of lubrication engineering at Kodak.

First, the best lubricants available must be used. This implies careful investigation of all new developments as they might apply to Kodak needs.

Second, the smallest practical number of different lubricating materials must be used to meet the greatest possible number of requirements. Along this line, special lubricants in use must be regularly and carefully scrutinized for purposes of reappraising their usefulness.

Third, especially in connection with the unusual and rigid requirements of the Kodak operation, lubrication schedules and application procedures must be carefully established and tested. With minimum safe quantities in use, accuracy and freedom from contamination are imperative. Careful observation of the performance and quality of all lubricants under actual operating conditions is also a must.

Fourth, and probably most important, is the necessity that machinery be operated at peak efficiency at lowered maintenance cost. This involves striving for longer and longer operating periods between scheduled routine maintenance checks as well as the prevention of failures.

THE RESULT

The most impressive testimony to the success of the program of lubrication engineering at Kodak is its endorsement by a careful and practical management. The annual budget provision for lubrication engineering is approximately twice the entire cost of lubricants used in the plant!

This apparent paradox proves not only that tremendous savings have resulted from simplification of lubricating procedures but that even greater savings are traceable to production gains and reductions in maintenance cost. It is estimated that routine maintenance requirements, and the production time loss that follows, have been reduced by as much as 60 to 70 percent due to improved lubrication practices and special care in bearing design and application.

But even more significant than cost savings are the implications of what has been achieved at Kodak for the future of the entire field of lubrication engineering. Kodak's program proves that a truly objective technical approach to lubrication problems, seeking the cause as well as the cure, is the key to both maximum results and maximum acceptance.

An automatic packaging machine is shown in operation in the Kodak Park Works plant of Eastman Kodak Company, Rochester, N.Y.

Fundamental Processes in Lubricating Metal S

by E. N. Klemgard,
Chemical Engineering Research Section
Washington State University
Pullman, Washington

Processes occurring in nickel alloy-solid lubricant systems operating in air, within the 100F to 1700F range have been investigated. Friction, wear, and surface damage involving multi-component solid lubricants containing graphite, boron oxide, silver chloride, sillver fluoride, metal phthalocyanine, molybdenum disulfide, lead oxide, and sodium silicate were calculated.

The controlling processes are: (a) Physical and Chemical Changes in the Surface Layers, (b) Changes in the Metal Substrates, and (c) Changes in Bulk Lubricant Film. In addition to the basic processes prevailing in boundary lubrication with conventional lubricants at temperatures below 200F, the high temperature ranges with solid lubricants, include processes covering variable yield and shear strength, hardness and diffusion of the substrates. Chemical reactions (decomposition, oxidation, reduction, and combination to form new compounds) are activated in the surface and bulk films. Processes involving adherence, metal solubilities, lubricant solubilities, and changes in the shear properties of the lubricants are most important.

Presented at the
15th ASLE Annual Meeting,
in Cincinnati, Ohio, April, 1960

INTRODUCTION

Many investigators have drawn attention to the importance of composition and nature of the materials forming the film, the mutual solubility of the metals, and the strength and hardness of the materials in the system (1). From the results of published investigations, it is clear that the systems under study are frequently exceedingly complex, and various processes may occur simultaneously in a single run in an experimental bearing.

Definition

Processes are operations in which there are changes of at least one physical or chemical characteristic of a material in the system.

From the standpoint of physical chemistry, processes are classified as being:

(c) Spontaneous or natural
(b) Nonspontaneous, or
(c) Reversible

Of most importance in the investigation of high temperature lubrication are the nonspontaneous processes, in view of the application of pressure, mechanical and thermal energy from outside the lubricated system.

The following classifications list some of the applicable fundamental processes reported in the literature (1 to 6) and are not entirely based on the author's experiments. It is recognized that there is great need for basic research in this area. However, until the basic processes of greatest importance have been identified and explored, basic research of a random nature is resorted to, and in many cases, has been rewarding.

tal Surfaces at 100F to 1700F

CLASSIFICATION OF FUNDAMENTAL PROCESSES IN HIGH TEMPERATURE LUBRICATION 100F TO 1700F

A. Surface Layer Processes

1. Physical Processes

(a) Transient temperature effects (hot spots), melting.

(b) Changes in surface finish, contact area, and shear area of the asperities. Polishing mechanism. Ploughing.

(c) Surface damage processes; checking, galling striation, metallic transfer.

(d) Wear of attached films and their failure.

(e) Changes in surface crystal faces, due to atom migration along "terraces", causing defects.

(f) Changes in lattic spacings of surface crystals due to stress and friction forces.

(g) Adhesion between metals, between oxide films, or other layer materials, which may be mechanically abraded.

(h) Introduction of solid lubricants into the interstices between the surface asperities; and the feeding or flow characteristics of the lubricant into and out of such spaces.

(i) Physical adsorption and desorption. Involves relatively weak van der Waals forces.

(j) Wettability of metal surface or surface layer. (Glass forming oxides.)

2. Chemical Processes

(a) Oxidation of metals (corrosion).

(b) Reactions of metals with halides, sulfur compounds, nitrogen, etc. (corrosion).

(c) Chemisorption, and film stability over the temperature and pressure ranges.

B. Substrate Processes

1. Physical Processes

(a) Fatigue failure due to alternate heating and cooling; pressure cycles.

(b) Changes in ductility (% elongation) and impact strength over the high temperature range.

(c) Hardness variations with temperatures. Thermal softening. (High compressive strength necessary for high load capacity.)

(d) Phase changes due to temperature variations.

(e) Changes in mutual solubility of metals and of alloying elements, due to chemical alterations in substrate.

(f) Changes in the activation energy requirements for metal to metal adhesion (are of the same order as for stress relaxation and creep).

2. Chemical Processes

(a) Internal Oxidation (via impurities) to increase hardness. (Precipitation hardening.)

(b) Diffusion of O_2, halides, etc. Bulk diffusion. Grain boundary diffusion. Changes in rheological properties due to grain boundary chemical reactions.

C. Bulk Film Processes

1. Physical Processes

(a) Temperature-Viscosity changes (Rheology).

(b) P-V-T processes. Bulk modulus. Changes in hardness in the bulk film, due to pressure or temperature changes.

(c) Changes in frictional properties with chemical alteration of film material. Physicochemical processes.

(d) Loss of material from lattice-layer anisotropic material, increasing its shear value. (Graphite at high temperatures.)

(e) Formation of films of oxides of extremely high degree of liquid immiscibility and solid insolubility (B_2O_3 — PbO; B_2O_3 — CoO).

(f) Loss of material from bulk film by sublimation or evaporation.

2. Chemical Processes

(a) Thermal decomposition of lubricants (Ag_2O or CuO, liberate oxygen at interface, forming bearing metal oxides.)

(b) Activated chemical reactions between the materials in the bulk film; oxidation, reduction, combination to form complexes.

DIFFUSION

In several instances, chemical attack and diffusion have been proposed for penetration of the metal surfaces to provide dry lubrication for long time periods (5) at high temperatures. Molybdenum has been treated with active sulfur compounds to form MoS_2 in situ, which has shown 0.07 f values when the metal was above 1000F. Halogens have frequently been proposed for this purpose, and the author has studied the diffusion of Cl, Br, I, and F through ferrous and nickel alloys since 1956. This work has shown that very complex chemical and physical processes occur. Numerous metallo oxyhalide salts are formed, metals in the halide salts are reduced, and halogen diffusion takes place. The predominant processes are probably:

$$MF_2 + M^1 = M + M^1F_2 \qquad [1]$$

Thermal decomposition:

$$MF_2 = M + F_2 \qquad [2]$$

Typical products possible are: MM^1F_3; $M_2M^1F_4$; MM^1F; $M_3M^1F_6$. With oxygen at the high prevailing temperatures MM^1OF, MOF or M^1OF (oxyfluorides) are formed.

From Fick's diffusion law:

$$X^2 = 4ADt \qquad [3]$$

where: X = diffusion depth after time, t.
D = coefficient of diffusion.
A = a constant relating the concentrations of the diffusing element at depth X, and at the surface.

Both D and A are determined experimentally. The nature of diffusion produced by a NaF — LiF flux is shown in Fig. 18.

MATERIALS AND APPARATUS

Nearly all of the specimens used in the experimetal work were machined from a commercial Ni-C Co alloy and had the following analysis:

Element	% by weight
C	0.05
Al	3.05
Ti	2.89
Mo	4.20
Cr	19.50
Co	19.30
Si	0.09
Mn	0.10
Fe	0.26
Zr	0.01
Cu	0.10
S	0.005
B	39 ppm
Ni	Balance

Heat Treatment

2150F; 2 hrs AC
1975F; 4 hrs AC
1550F; 24 hrs AC
1400F; 16 hrs AC

Rupture Stress

Life, hours; 196.8
Stress; 21,000 psi
Temperature; 1700F
% Elongation; 9.8
% RA; 12.3

Apparatus

Fig. 1 is a diagram of the major components of the friction rig. Fig. 2 shows the size and geometry of the shaft and V-blocks used as specimens. Fig. 3 is a photograph of the test specimens, mounted in place in the furnace. A general view of the friction apparatus is shown in Fig. 4. Torque is measured by the displacement of a pendulum attached to a differential gear in the drive system. Temperatures are taken with a thermocouple in contact with the lower V-block.

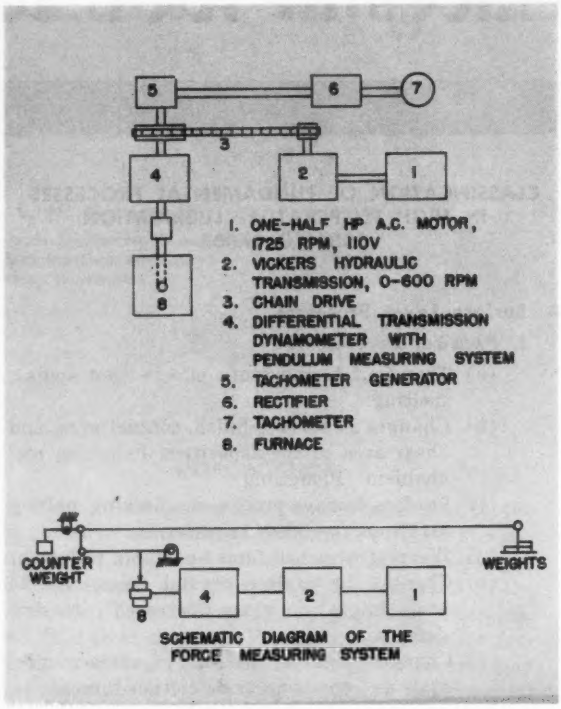


Fig. 1. DIR High Temperature Friction Tester.

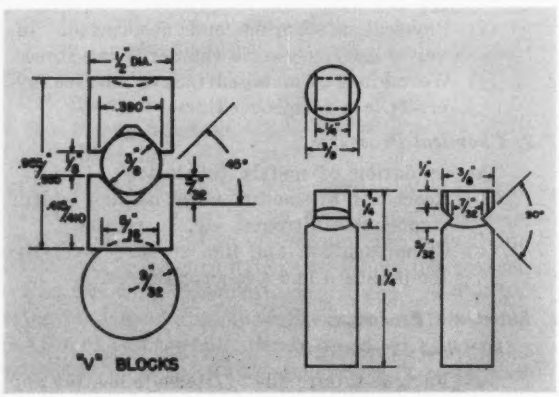


Fig. 2. Specimens for DIR High Temperature Friction Apparatus.

Fig. 3. View of ⅜-inch shaft, V-blocks, drive mechanism, thermocouple location and heating coils.

TEST PROCEDURES FOR THE D I R HIGH TEMPERATURE FRICTION AND WEAR APPARATUS

A. Coefficient of Friction vs. Temperature (19 minutes total)

. *Break In,* (room temperature, surface speed 3.5 ft/min.)

a. One minute at 100 pound load.

b. One minute at 200 pound load.

c. One minute at 300 pound load.

2. *Temperature Increase* (300 pound load held constant)

The temperature of the specimens in the electric resistance furnace is increased 100F each minute by hand-controlled rheostat to 1700F after the three minute break-in period, the first temperature reading being 200F.

3. *Coefficient of Friction*

The torque in inch-pounds is recorded at one minute intervals and the coefficient of friction, f, is calculated from the equation

$$f = \frac{1}{D \sin 45} \times \frac{T}{L}$$

where D = test shaft diameter
T = torque between blocks and shaft
L = load perpendicular to the test specimens

4. *Tabulation of Data*

For each run a graph is plotted with coefficient of friction on the ordinate and time, linear feet the shaft surface travels, and temperature; each with a separate scale, on the abscissa.

RESULTS AND DISCUSSION

In several comparable runs, with temperature increase rates at 100F/minute, and 20F/minute (5 minutes at each 100F increase) the shapes of the friction-temperature curves were very similar. In some cases friction for the 5-minute periods was less in the 100F to 1000F range, and higher in the range of 1000F to 1700F. It is believed, however, that the 100F/minute rate affords a rapid, significant method of evaluating a lubricant, and to some extent simulates temperature increase rates that may be encountered in space vehicle applications. Fig. 5 shows views of pure nickel-shaft

Fig. 4. General view of friction apparatus, with lever system raised, exposing interior of furnace.

Fig. 5. Mass failure of nickel shaft surfaces at 200F. W = 300 lbs., 3.5 ft/min. Failures occurred after only 3 minutes operation. (Left) Pretreatment; none. (Right) Specimens previously fired at 1500F for 30 minutes. f = 1.615. (X210).

specimens, and the catastrophic mass failure which occurred in less than three minutes at a temperature of 200F and a 300-pound load. The oxidized nickel shaft on oxidized nickel blocks gave very little improvement at the 300-pound load. The friction value recorded was 1.615. Titanium versus titanium, and other pure metal pairs resulted in excessive galling. From Fig. 6, for comparable evalutions of unlubricated Ni-Cr-Co alloy, it is seen that 16-minute and 60-minute runs were possible, although friction varied in the 0.60 to 1.65 range. Fig. 7 for the 16-minute run shows an increase in friction to 1.65 at 1200F, at which time and temperature, with probable multiple oxide formation initiated reductions in the frictional values to 0.621 at 1700F. After 60 minutes of operation at 1500F (Fig. 8), friction remained nearly constant at 0.62. The wear scar area for the 16-minute run (331), Fig. 7, was 0.1324 square inches and after 60 minutes at 1500F, was 0.1436 square inches. These values are considered excessive for commercial purposes, but are, of course, great improvements over the pure metal results. Such results reveal the possibilities for the substantial improvements in friction and wear that are made possible by the processes that occur with complex Ni-Cr-Co alloys in the 100F to 1700F range, but which are evidently not effective in the case of pure nickel.

To further explore the possibilities of reducing the friction and wear levels of this alloy and elucidate the various processes involved, 230 screening evaluations were completed, in the 100F to 1700F range, with single and multi-component lubricants, under controlled operating conditions. Results are reported as a friction factor, or the percent of the time during which f was equal to or less than 0.300. To accomplish brevity the results of only ten of the 230 friction and wear tests are presented in Table 1. The cases discussed are typical, and represent neither the most favorable or the least desirable lubricants.

For Runs K-1 through K-86, numerous evaluations of lubricants were made in various multiple combinations. The following compounds were utilized in lubricants which resulted in friction factors of 0%:

B_2O_3, AgF, MoS_2, AgI, AgF, LiF, NaF, PbO, SbF, BN, Na_2MoO_4, TiC, Cu_2O, CuS, CuO, Ce_2O_3, Ce_2S_3, CeF_3, GeO_2, Cb_2O_5, Sb_2O_3, SnO_2, TiO_2 Ws_2, BeF_2, Na_2SIO_3, PbS, and graphite.

Work with these compounds resulted in one or more cases for each in which all of the friction values were above 0.300 in the 200F to 1700F range (Friction Factor, 0%). Formulation, bonding and pre-treatment may be such that only high frictional values resulted. In many of the screening tests, it was found possible to obtain friction factor results, in the 30% to 80% range by suitable choice of bonding agents (such as B_2O_3) and adjusting the relative concentration of pairs and multiple compounds. From the experimental evidence produced, it has been possible to develop process techniques covering the application and use of the foregoing well-known solid lubricants to the extent that the f factors fall in the 50% to 100% bracket. In future phases of the work, the friction factor maximum f value will be established at f = 0.200, and the final phase will be for f = 0.100, over the 200F to 1700F range.

Run K3 With a mixture of B_2O_3 and silver fluoride, a minimum f value of 0.089 was attained at the final temperature of 1700F, with a maximum f value of only 0.519 at 800F. When B_2O_3 alone was run, f was 0.400 at 800F. It is therefore believed that reduction

Fig. 6. Surfaces of Ni-Cr-Co shafts; (Left) 331, after 19 minutes, 100 to 1700F., no lubricant, f = 0.811, showing metal smears and sheared areas. (Right) same metal after 60 minutes operation at 1500F., showing deep stria in absence of lubricant, f = 0.621. (X210)

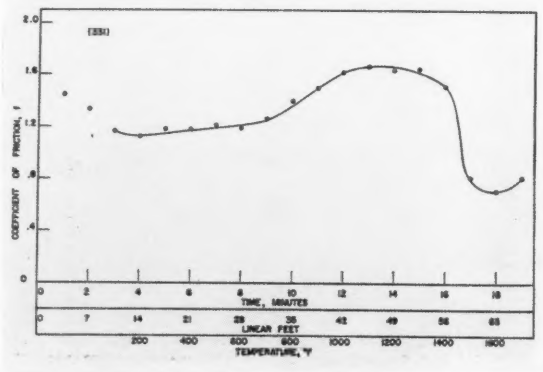


Fig. 7. Ni-Cr-Co specimens, no lubricant. Pretreatment 1500F. /30 minutes.

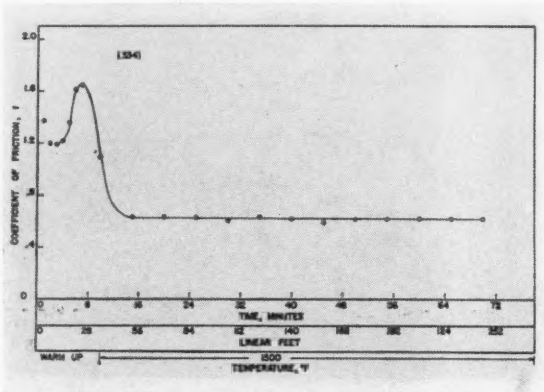


Fig. 8. One-hour life test, Udimet 500; Pretreatment, 1500F /30 minutes.

TABLE 1—SUMMARY OF FRICTIONAL DATA* AND SURFACE DAMAGE AREAS

Run No.	Lubricant** and Pretreatment	Computed Pressure psi	Total Scar Area in²	f		f_f0.30
				min.	max.	
331	No lubricant 1500 F/30 mins.	4,530	.1324	.709	1.659	00.00
334	No lubricant. 70 min. life test. 1500 F/30 mins.	4,180	.1436	.596	1.646	00.00
K-3	B_2O_3; AgF 1500 F/30 mins.	8,750	.0688	.089	0.519	50.00
K-14	B_2O_3; graphite 1500 F/30 mins.	16,480	.0364	.076	1.026	56.25
K-25	Metallo-phthalocyanine B_2O_3 graphite; AgCl. 1500 F/30 mins. Additional graphite+cyanine	9,090	.0660	.051	0.405	81.25
K-28	B_2O_3—AgCl; Metallo-phthalocyanine, phenolic resin. 1500 F/30 mins.	3,968	.1512	.076	0.697	43.75
K-29	B_2O_3—AgCl; graphite, phenolic resin 1500 F/30 mins.	5,225	.1148	.101	0.722	50.00
K-70	Na_2SiO_3—MoS_2—graphite 1500 F/30 mins. (23A)	3,978	.1514	.329	1.051	00.00
K-77	Na_2SiO_3—Pb_3O_4—graphite. 275 F/16 hrs.	12,400	.0487	.038	0.291	100.00
K-78	Same as K-77 1500 F/30 min.	7,230	.0832	.114	0.532	31.25

*f_f = The % of Run Time f = 0.300 or less.

**Dry solid lubricants ground for 1 hour, prepared as a slurry in isopropanol, and applied to specimens by brushing.

in friction to 0.304 (Fig. 9) at 1000F was caused by reduction of the viscosity of the B_2O_3 to an effective hydrodynamic lubricant. The viscosities of B_2O_3 have been estimated as follows: (7)

VISCOSITY OF B_2O_3		TEMPERATURE °F
Reyns	*Poises*	
0.035	2,400	1100
4.370	300,000	900

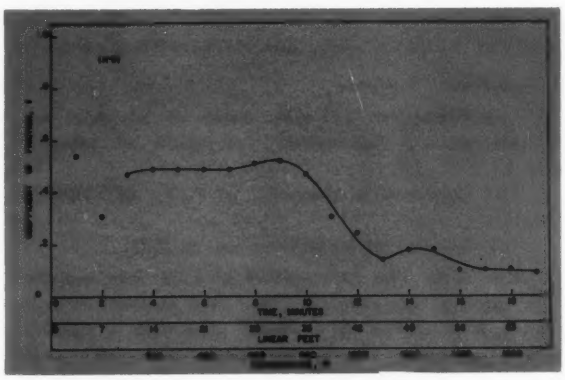


Fig. 9. B_2O_3-AgF Lubricant; Ni-Cr-Co specimens. Friction factor = 50.0%.

However, with B_2O_3 alone, friction increasse sharply at 1100F to f of 0.400 or greater; but in the presence of AgCl, f was only 0.139 at 1200F (Fig. 9), possibly due to the low frictional value of the halide, the presence of thin films of reduced metallic silver, and slight diffusion of chlorine. The basic processes may then be considered as: (a) Hydrodynamic lubrication (800F to 1200F, fluid B_2O_3); (b) Formation of adsorbed films of metallo-halides; (c) The deposition of thin films of metallic silver which was visible and verified by chemical analysis; and (d) Diffusion.

Run K-14 From Fig. 10, it is seen that apparently for B_2O_3 and graphite, the fundamental processes were:

(a) Anisotropic shear effects of graphite maintained f at less than 0.3 from 100F to 500 F. With B_2O_3 *alone*, f varied from 1.10 to 0.910 in the same temperature range.

(b) At 500F to 600F, f increased from 0.3 to 1.0, a rapid ascent attributed to desorbtion phenomena, whereby the graphite has apparently lost its low anisotropic shear properties, or has undergone displacement processes due to the presence of plastic B_2O_3, and has not adhered to the surfaces.

(c) Oxidation processes at the surfaces of the Ni-Cr-Co alloy in the 500F to 1000F range were appar-

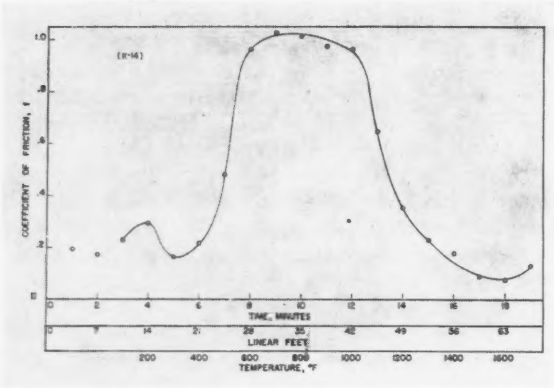


Fig. 10. B_2O_3—Graphite Lubricant. No. AgC1. Shows effects of graphite at temperatures above 1200F. Friction factor = 56.25%.

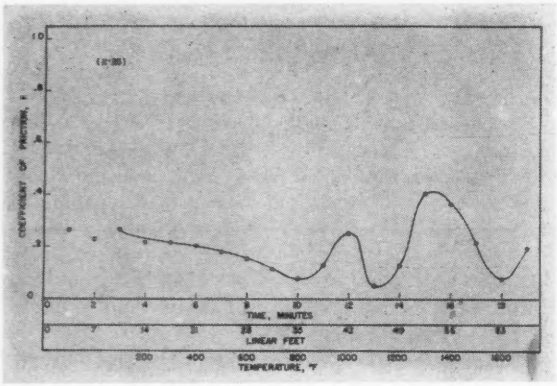


Fig. 11. B_2O_3; Griphite; AgC1; Metallo-Phthalocyanine, Lubricant. Friction factor (% of time f = 0.30) was 81.25%. Cyclic effects due to concurrent favorable and unfavorable rate processes.

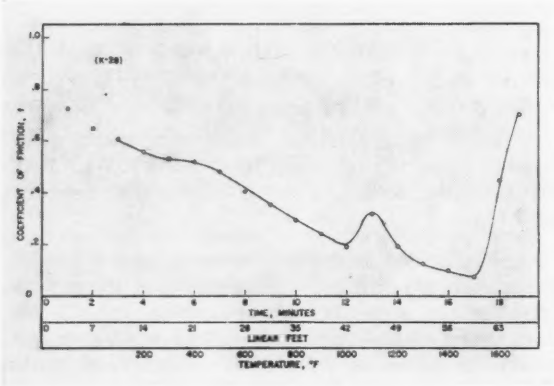


Fig. 12. B_2O_3; AgC1; Metallo-Phthalocyanine, Lubricant. Friction factor = 43.75%.

ently ineffective (quantitatively or qualitatively) in friction reduction.

(d) At 1000F, the hydrodynamic effects of molten B_2O_3 became appreciable. With B_2O_3 alone, in a comparable evaluation, f reached a low value of 0.2 at 1000F, but at 1400F had increased to 1.2, probably due to its viscosity decrease to less than 2,400 poises. However, with the dispersion of fine graphite in the fluid B_2O_3 in the 1200F to 1700F range, f varied within the low limits of 0.76 to 0.228, the graphite tending to increase the viscosity of the B_2O_3. Other processes in the bulk film having possible favorable synergistic effects are (a) solution of abrasive oxides in the fluid B_2O_3, and (b) the protection of the graphite with the fluid to prevent loss of the impurities from the graphite by sealing effects at the lamellar edges to preserve low anisotropic shear values.

Run K-25 By adding a metallo phthalocyanine and AgC1, to the B_2O_3-graphite of Run K-14, the friction factor was improved to 81.25% (Fig. 11). At 1000F, there was a friction peak (f = 0.250), but much less than the 1.0 value for Run K-14. Processes responsible for this reduced friction must be attributed to the presence of the cyanine and the AgC1, as are the low minimum value of 0.051 f at 1100F, and 0.076 value at 1600F. Friction factors for various phthalocyanines alone and graphite alone were: metal free phthalocyanine (12.5%), cobalt phthalocyanine (18.75%), zinc phthalocyanine (43.75%), and graphite (0%). The possible processes controlling these variations in friction are:

Surface Processes

(a) The cyanine may act to cause better adherence of the graphite to the surfaces. This enhancement was particularly effective up to the transition at 800F. Preferential reactions may occur between the alloy and cyanine, and this new surface could in turn, form compounds with graphite.

(b) Chemical reactions at the surfaces have occurred between the AgCl and Ni, Co, Cr, etc., whereby low shear chlorides of the alloy constituents are formed and some free silver has been identified. Some of the shear areas are free silver on the alloy asperities. Some of the material in the surface film is of the MOCl type.

Subtrate Processes

(a) Diffusion of Cl at grain boundaries (only trace diffusion in Ni-Cr-Co alloy.)

(b) Continued internal oxidation of minor constituents of Ni-Cr-Co alloy, and increased hot hardness.

Bulk Film Processes

(a) Formation of compounds of graphite and phthalocyanine; interstitial compounds of graphite with Cl.

(b) Decrease in viscosity of B_2O_3, at 1100F to 1400F.

(c) Solution of metallic oxides in B_2O_3.

Run K-28 The formulation of K-25 was modified to eliminate the graphite; and the metallo-phthalocyanine was applied in a second step with a phenolic resin as a binder. The friction factor dropped sharply from 81.25 for K-25, to 43.75 for K-28 (Table 1). At 1500F (Fig. 12), f increased rapidly from 0.076 to 0.697 at 1700F. The lack of the low shear value

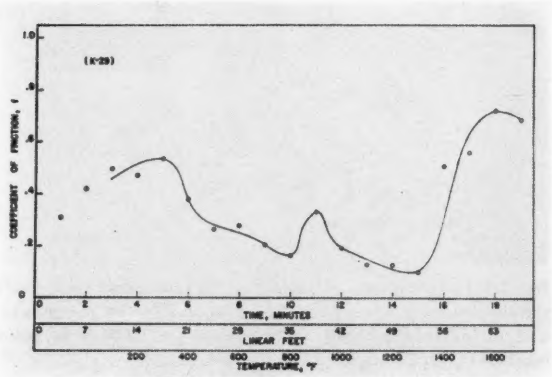


Fig. 13. B_2O_3; AgCl; Graphite; Phenolic Resin, Lubricant. Friction factor = 50.0%.

graphite was apparent; and the processes based on AgCl reactions effective to the transition at 1500F were inadequate in the 1500F to 1700F range.

Run K-29 By restoring the graphite to Lubricant K-28 (as in K-25), but eliminating the metallo pythalocyanine, a friction factor of only 50.0% was attained (Fig. 13). This suggests that processes based on the ternary formulation, "graphite-metallo-pythalocyanine-AgCl", in B_2O_3 are capable of enhanced low friction effects over the 200F to 1700F range, even after being fired at 1500F for 30 minutes. The processes for attaining a friction factor greater than 80%, by application of these reactants, were discussed in detail under Section K-25.

Run K-70 Processes responsible for the failure of Na_2SiO_3-MoS_2-graphite lubricants at temperatures above 1500F, are revealed in Fig. 14. The prefiring at 1500F has apparently caused the graphite to lose either its low anisotropic shear characteristics, or the Na_2SiO_3 has become ineffective in bonding the lamella to the Ni-Cr-Co alloy surfaces. Oxidation of the MoS_2 had progressed to the extent that it was no longer effective as a lubricant in this system (Fig. 15).

Runs K-77, K-78, With Pb_3O_4, Na_2SiO_3, and graphite as a typical ternary lubricant, Run K-77 was not prefired, and Run K-78 involved static heating for 30 minutes at 1500F (as in the normal evaluations). The friction factor for K-77 was 100%, whereas the factor for K-78 was only 31.25% (Fig. 16).

It was obvious that the non-spontaneous processes resulting from the static thermal treatment can produce increased friction and failures when the specimens are evaluated for friction and wear in the 200F to 1700F range. In this comparison, the greatest differ-

Fig. 15. A MoS_2 lubricant, K-70, which resulted in mass failure and galled streaks. The friction was 0.0; and f at 1700F was 0.608. Wear scar area was 0.151 sq. in. This combination of Na_2SiO_3, graphite, and MoS_2 was ineffective as a lubricant over the 200F to 1700F range. (X210)

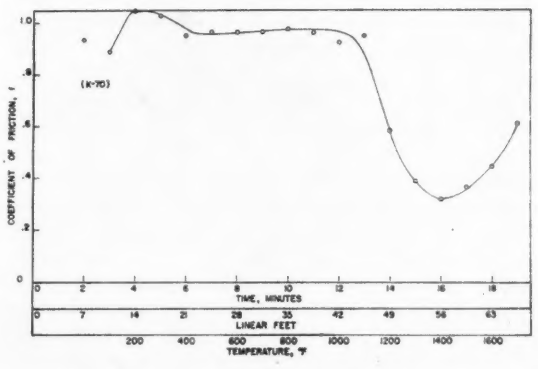


Fig. 14. Na_2SiO_3-MoS_2-Graphite. Friction factor = 0. This formulation allows unfavorable oxidation processes to occur.

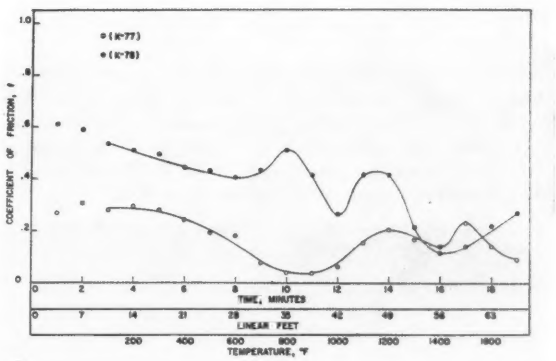


Fig. 16. Lubricant for K-77 and K-78 was Na_2SiO_3-Pb_3O_4-graphite. For upper curve (K-78), specimens coated and fired at 1500F/30 minutes. For lower curve specimens coated and cured at 275F/16 hours.

ences were noted at temperatures below 1300F (Fig. 16). From 1400F to 1700F, the frictional values were of the same order, indicating that prefiring under static conditions may activate reactions similar in their effects to those produced by high temperature dynamic operation. For this reason, the use of the static prefiring cycle is considered of importance in comparing longevity of these lubricants.

Plastic Deformation and Galling

The results of plastic deformation and hot working in producing fatigue failure and mass galling are shown in Fig. 17.

Diffusion

Typical diffusion of 303 stainless steel by fluorine, is shown in Fig. 18.

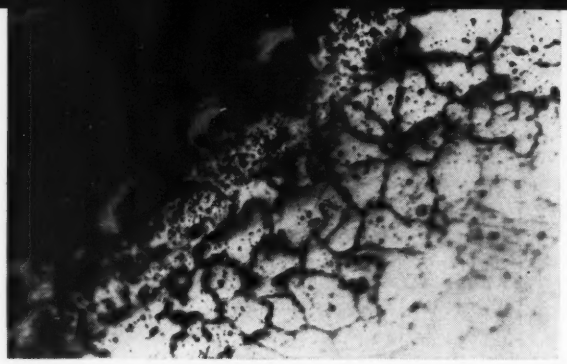


Fig. 18. Metallograph of section of 303 stainless steel shaft showing surface films of cerium-oxygen-fluorine complexes, and diffusion attributed to fluorine from LiF-NaF in solid lubricant flux. f = 0.331 (X1000) Run 142.

CONCLUSIONS

With increasing temperatures, the physical and chemical changes in the *surface layers*, in the *metal subtrates* and in the *bulk lubricant films*, become of great importance and new processes not prevailing in low temperature applications are frequently responsible for catastrophic mass failure of the bearing surfaces. Of particular interest in this connection are:

(a) Diffusion. (Fig. 18)

(b) Chemical reactions in the lubricant film activated by temperatures to 1700F; thermal decomposition, oxidation, reduction, combination to form new compounds and complexes and others.

(c) Processes controlling adherence of solid lubricants to surfaces.

(d) Metal solubilities, and lubricant solution processes, particularly for oxides.

(e) Processes involving changes in the anisotropic shear properties of materials in the system.

By investigation of the numerous simultaneous processes occurring in lubricated systems at high temperatures, it is possible to elucidate many of the complex relationships between friction and temperature. However, since two or more processes may function in a synergistic manner and other mechanisms may operate in an opposed or adverse way, the friction-temperature relationships are indeed complex. The techniques for the further study of these fundamental processes related to friction and wear have been indicated.

Fig. 17. (138) Photomicrograph (X250) of the surface of SAE 3135 steel, showing work checks at 90° to galled stria, which was an intermediate step leading to mass failure. The sulfide lubricant was in a NaF-LiF lux. The checks are due to hot working (above 1000F.) at 13,920 psi load, W; and a friction force F, of 6,680 psi, (f = 0.48).

ACKNOWLEDGMENTS

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Grease Worker Results and Their Significance in Anti-Friction Bearing Lubrication

by Earl Sillett

Canadian Westinghouse Company Limited,
Research and Development Laboratories,
Hamilton, Ontario, Canada

Presentation before the ASLE Local Sections
Montreal—December 2, 1959
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The grease worker has been under criticism because there appears to be a lack of correlation between laboratory results and field experience. This paper discusses some of the factors that should be considered in drawing proper conclusions.

The presence of vibration and the overpacking of bearings with grease are important factors, and when considered with other effects do tend to support the fact that the grease worker results are valid.

Some attempts have been made to show the importance of cooperation between various groups in obtaining information that may be useful when conducting such a program.

It should be noted that the initial NLGI classification of a grease is changed once the grease has been in operation in a bearing for any length of time.

The working of greases and some field observations are discussed in this paper.

INTRODUCTION

The purpose of this paper is two fold. First to emphasize the importance of maintaining a close relationship between the service man and the analyst who studies lubrication problems. The second purpose of this paper is to attempt to bridge some of the gap that exists between the professional man and the maintenance man.

First the analyst has more time to study the problems and to collect data from various sources. He is in a position to co-ordinate data and field observations and to disseminate his findings to the service man dealing with a particular problem. It is the service man's duty to work with the analyst by confirming or denying the analyst's findings. This kind of teamwork builds up a solid foundation of observations which may be used to deal accurately with more difficult problems.

The service man has just as important a function in the organization as any other person. Investigational programs conducted without the cooperation of the Engineering, Quality Control and the Service Departments would be folly.

Secondly the gap will continue to widen unless there is some attempt to understand each other and to speak the same language. To illustrate, a service man has a complaint about a noisy bearing in an electric motor. He checks the bearing but can find nothing to indicate the cause of trouble. The bearing is then sent to the Laboratory for complete examination. The analyst finds no defects in the bearing but he notes little feathers of grease protruding from the cage between each of the ball spaces (Fig. 1). A series of co-operative

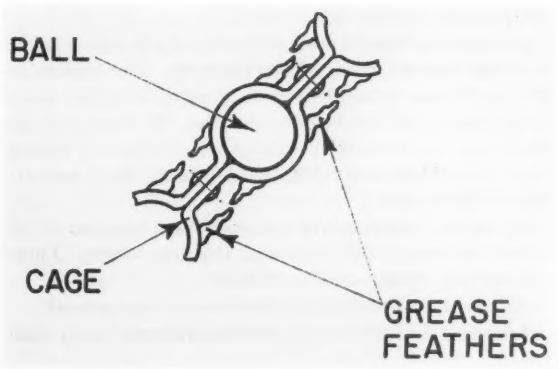

Fig. 1. Feathering of grease caused by the presence of vibration.

investigations indicated that vibrational noises external to the bearing were the cause of this feathering phenomena. Hence both parties have developed an observation which assists them in future investigations. The grease worker tests and their application to antifriction bearings were part of an over all programme whereby bearing failures were studied by the Laboratory, Quality Control, Engineering and Service Department. It was this co-operative effort that brought to light some of the points outlined in this paper.

The grease worker is used to measure the consistency of greases after being worked. The grease manufacturer uses this instrument to assist him in producing a grease of uniform consistency from batch to batch. The customer may use this instrument to help control the quality of the product to be used in his bearings.

The consistency of the grease is measured before and after it is worked. Some investigators are continuing to work the grease for longer periods of time to study the effects of working.

The working of greases and a few field observations are discussed in this paper. Attempts have been made to interpret these findings.

GREASES

It is important to know something about greases themselves before proceeding with the study of worked greases.

To start with a grease generally is a mixture of petroleum oil and a metallic soap. Lubricating greases in their common form are smooth plastic masses having a consistency similar to butter. The resistence of greases to deformation by relatively small forces as well as its general physical and chemical characteristics are subject to wide variations. The kind of soap used to make the grease, the processes by which the ingredients are combined and the presence of other substances in the finished products such as water, glycerin affect the variations of consistencies in greases.

The consistency or plasticity of the grease and its resistance to change upon being worked is the subject of investigation. It is important to realize that greases consists of soap fibers that are generally linear and of varying lengths. These soap fibers form a tangled, three-dimensional, lattice-like structure within the body of the grease. The petroleum oil fills the spaces between these fibers. These fibers may be likened to a sponge which soaks up water.

The greases bleed small amounts of oil which lubricates the critical areas of the bearings. The grease itself also tends to migrate and is subject to the same shear forces of the bearing as the oil. Some of the fibers are able to withstand these shearing forces. Other soap fibers cannot withstand such shear and are quickly destroyed.

Three basic greases are discussed here because of the rather complete history available on them. These greases are designated as follows:

Grease A—a lithium stearate soap base grease.

Grease B—a lithium 12-hydroxystearate soap base grease.

Grease C—a sodium stearate soap base grease.

A study of Fig. 2 will show that the lithium atom is very small compared to the sodium atom. The long fatty acid chain is not readily affected by the small lithium atom and acts like a free fatty acid in some respects. This is not the case with the large sodium atom which does affect the properties of the fatty acid chain. For example the sodium stearate soap is soluble in water whereby the lithium stearate soap is not soluble in water.

A closer examination of the fatty acid chains will show that the only difference between them is that the 12-hydroxystearate contains a hydroxyl (OH) group which is attached to the 12th carbon atom. Despite this small difference, this fatty acid chain has been a great benefactor to man because of its ability to withstand higher temperatures and the forces of shear as will be shown later.

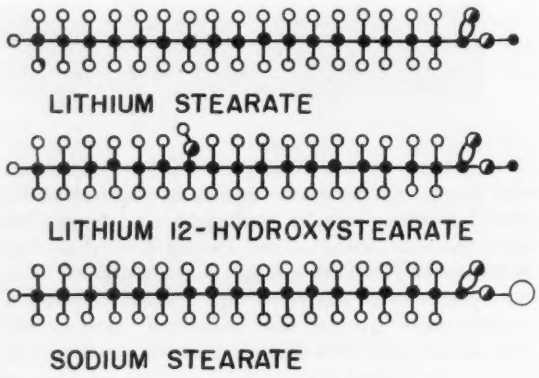

Fig. 2. The structure of the three basic soaps.

Table 1 shows some further properties of the three greases under investigation.

Table 1—GREASE PROPERTIES

	Grease A	Grease B	Grease C
Dropping Point (°F)	375	390	500
Oil Viscosity (SUS at 100F)	120	495	310
Soap Base	Lithium	Lithium	Sodium
Soap (%)	18	11	24
Worked Penetration (mm at 77F)	255	230	280
NLGI No.	2½	3	2

GREASEWORKER

The consistency of a grease is measured by the penetration of a metal cone having definite dimensions and weight (Fig. 3) into the surface of the grease. The penetration number indicates the depth in millimeters (mm) which the cone penetrates the grease when the cone is dropped into the sample from a given height. The device in which the test is performed is called a Penetrometer. A penetration may be performed on a grease as received. Generally the penetration is measured after the grease has been subjected to 60 double strokes at 77F in the standard greaseworker.

The three greases under investigation have been worked up to 100,000 double strokes. The penetra-

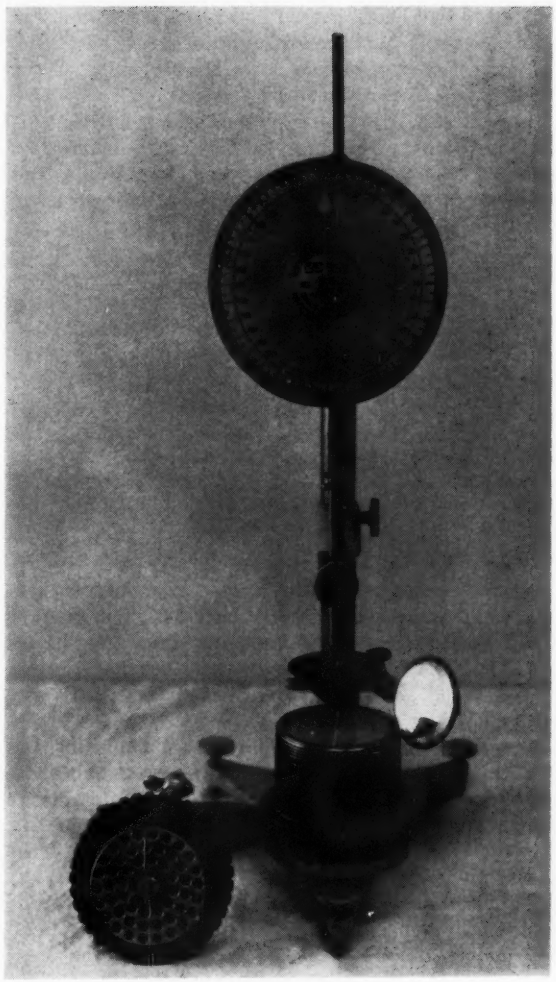

Fig. 3. The Penetrometer and the Grease Worker.

tions were measured at 0, 60 and each 10,000 double strokes up to 100,000 double strokes. The greases were worked with the standard ¼ inch hole plate in an air conditioned room maintained at 77F. The penetration of each of these points is plotted against the number of strokes as shown in the Fig. 4.

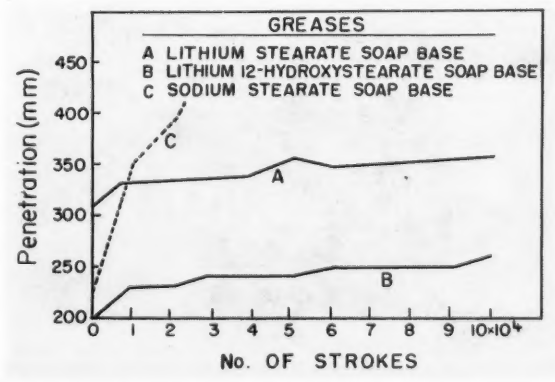

Fig. 4. The change in consistency of the three greases as they are worked.

The NLGI (National Lubricating Grease Institute) specifies seven standard consistencies (as shown in Table 2). The softer the consistency of the grease, the deeper is the penetration.

Table 2—NLGI Grease Penetration Table

Grade No.	ASTM Worked Penetration	Description
0	355—385	Semifluid
1	310—340	Very soft
2	265—295	Soft
3	220—250	Cup Grease
4	175—205	Cup Grease
5	130—160	Cup Grease
6	85—115	Block Grease

INTERPRETATION

This now becomes a problem of interpreting the results (shown in Fig. 4) to bearing applications. The three greases discussed in this paper have a good reputation in the field. At least this is what appeared to be the case when the investigation was initially started.

A different approach is attempted here in the following discussion. Examine the bearing illustrated in Fig. 5. A series of balls contained in a cage are traveling along the raceway. On each side of the raceway there is a wide shoulder. Grease sits on parts of the

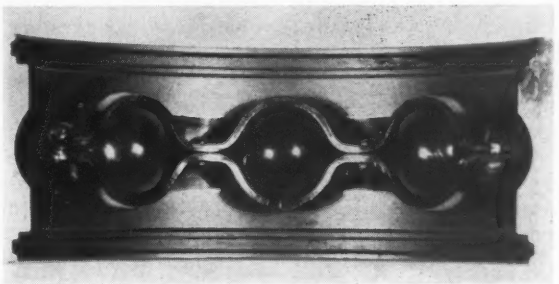

Fig. 5. Bearing section showing the wide shoulders on each side of the raceway along with the balls and cage.

cage and on these shoulders. The grease is not subjected to shear forces as long as it remains on the external parts of the cage and the shoulders.

The grease may be pushed or pulled into the ball path by several methods. For example a bearing that has been overpacked with grease leaves no room for the balls and cage to move. The grease in front of the balls is forced to one side while the grease already on the side is forced in behind the balls in order to make room for the grease extruded in front of the balls. Churning of the grease results, and the grease is subjected to heavy shearing forces. Not only is the grease subjected to heavy shear but the work done on the grease raises its temperature and the life of the grease is shortened. If dirt should gain entrance to such a system it will be churned into the critical operating areas of the bearing creating havoc.

The grease may also enter the operating areas of the bearing if its consistency is too low or if its consistency is lowered when subjected to the shear forces of the bearing. Good channelling greases will gradually

migrate to these areas and this migration can be accelerated if there is vibration present.

Examine Fig. 6. Any grease that enters the raceway is going to be subjected to shear and the balls will tend to eject this grease to one side. If the grease withstands the shear it will be shoved to one side. If, however, the grease is softened as in the case of grease A parts of the semi-fluid lubricant may be expelled out of the bearing if there are any passages by the seals for the lubricant to escape through. This was a complaint against grease A and yet in most of the cases there was still plenty of lubricant remaining to lubricate these bearings for a considerable length of time. Dirt was a problem where ever it gained entrance to a bearing since this grease would continually migrate to the operating areas carrying the dirt with it. This grease is now used only where very low temperatures are encountered. To date this grease has given an excellent performance in this application.

Now examine the curve of grease C and how it completely liquified on working. This is a good channelling grease and has given excellent service in a number of applications. Unhappily, however, where there is sufficient vibration present to make this grease slump into the operating areas of the bearing it is quickly liquified and is completely expelled from the bearing where the seals are not designed to hold liquids. This accounts for some of the complaints where no grease has been found in the bearing.

Grease B and greases similar to B have been used in place of grease C. In one case where a large gyratory crusher was destroying bearings at the rate of one a week, a grease similar to grease B was applied. These bearings have been operating for over three years and are still operating.

One large manufacturer made a 100% change to grease B and their failure rate became negligible. It is also interesting to note that this manufacturer suffered somewhat from incompatability of greases B and C when they were mixed in large spherical roller bearings.

Some claim that no harm is done if the grease does liquify, providing the seals retain the liquified lubricant. In a number of cases this has been observed. A double roll ball bearing used in a large fan motor was in excellent condition even though the grease had liquified. Vibration had broken down the structure of the grease but it was retained by the seals.

However, let us examine another case and draw conclusions from it. Examine Fig. 7, a large double row spherical roller bearing. These bearings contain a land riding cage. Land riding cages work well when the bearing is lubricated with oil. Grease C is applied and it is noted at point A between the high points of the rollers and the raceways that the grease has liquified. The grease at points C (the shoulders) and B (between the center land and the cage) is solid. Wear takes place between the center land and the cage because it is not receiving sufficient lubrication despite the fact that some of the liquified lubricant is sprayed up against these surfaces. It is interesting to note that despite the fact that some of the manufacturers call for a O consistency grease, there are other manufacturers using a No. 3 consistency grease and in some cases even a No. 4 consistency grease has been considered. Grease B has helped considerably.

An interesting investigation was conducted on several double row special roller bearings. The amount of lubricant to be used in these bearings was to be determined. The bearings were overpacked and the excess grease was allowed to extrude through a large anular opening at the back of the bearing. The excess grease extruded through the large anular opening and the bearing temperatures stabilized at 80 C. When the excess grease was removed the bearing temperatures made a further drop to approximately 40 C despite the fact that the bearing had already forced some of the grease out of the way.

To sum up, the grease results can be used as a guide post. Good channelling greases which have been liquified indicates the presence of vibrations or the presence of too much grease. Greases that show good shear resistance should generally show excellent results in bearing lives where stability is important. Excess grease causes undue churning and shortens the life of the grease and also the bearing if the work done on the grease creates high temperatures. Greases of different soap bases are not generally considered to be compatible with one another. The development of 12-hydroxystearates have made great contributions to the development of shear resistant greases.

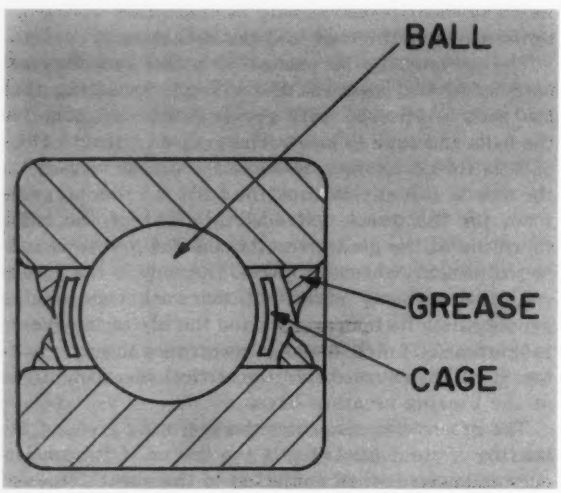

Fig. 6. Grease distribution on a ball bearing.

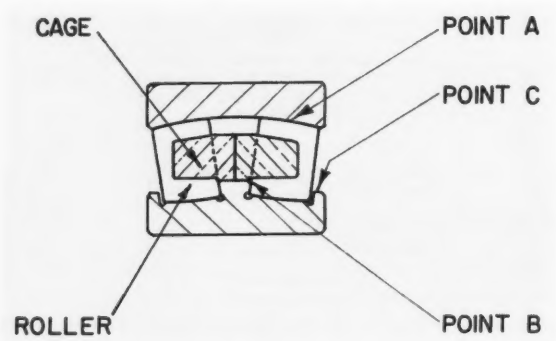

Fig. 7. A cross section of a double row spherical roller bearing.

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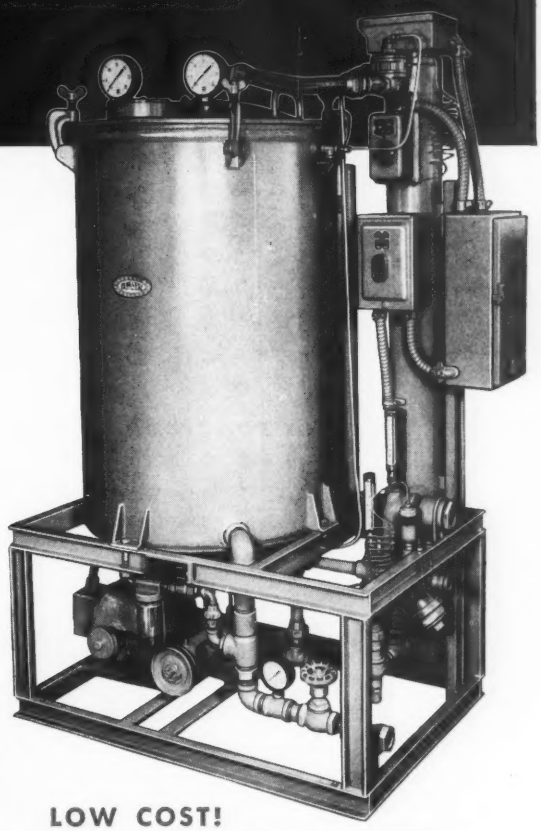

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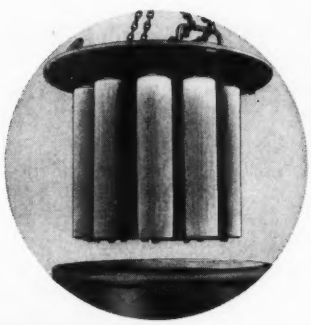

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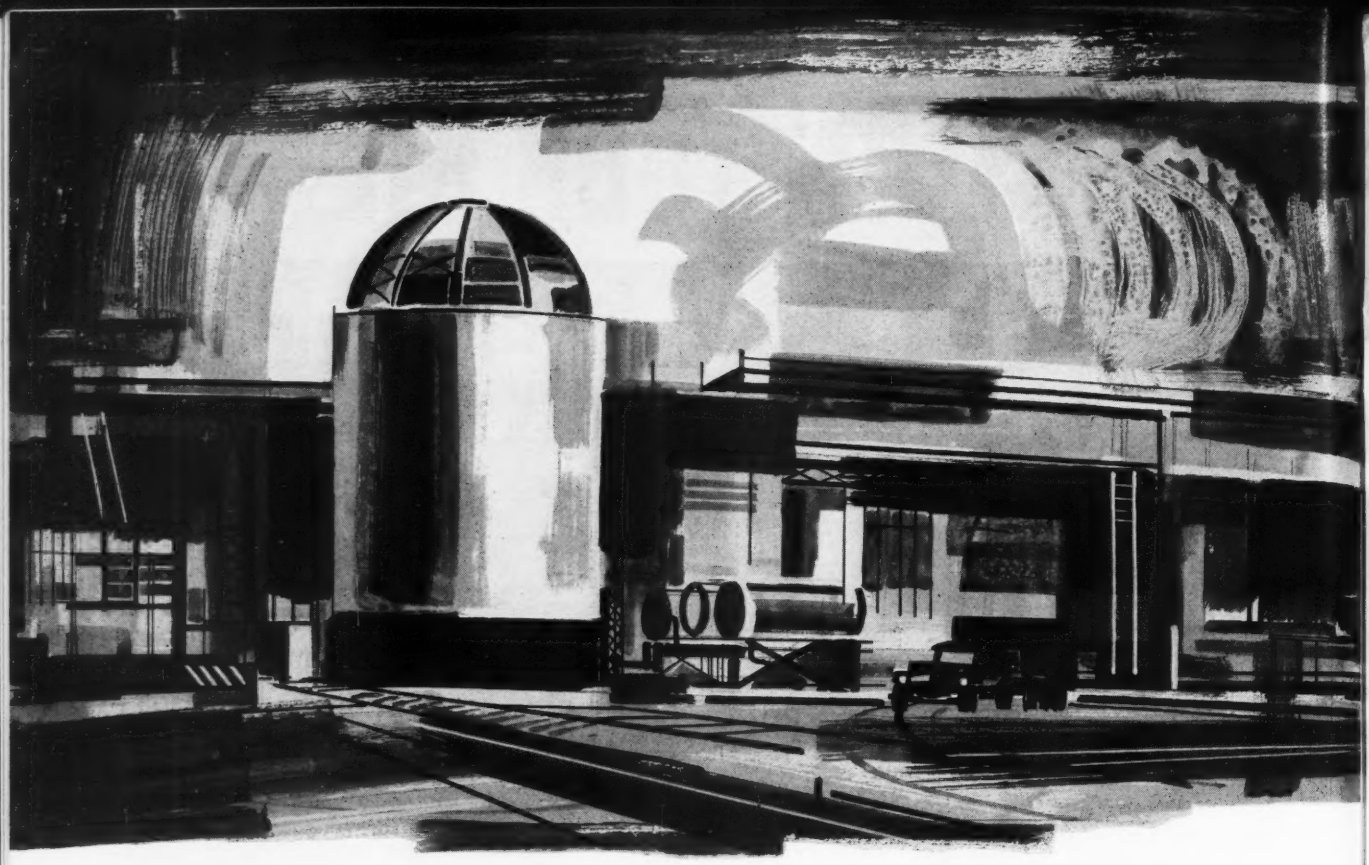

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Puget Sound	Ray Schaaf	Robert Jackson, General Petro. Corp., 11406 Glendale Way, Seattle 88, Washington	3rd Tuesday—711 W. Elliott Ave., Seattle, Wash.
Richmond	C. A. Chilson	R. Hendrick, Reynolds Metals Co., 3rd and Grace Sts., Richmond, Va.	2nd Monday
Rochester	Robert Hofmann	William Signer, Acheson Colloids Co., 132 Meadowbrook Rd., Rochester, N.Y.	2nd Wednesday—German Club, 315 Gregory St., Rochester, N.Y.
Saginaw Valley	D. H. Smallridge	Roy T. Browning, Dow Corning Corp., P.O. Box 592, Midland, Michigan	4th Thursday—Zender's, Frankenmuth, Mich.
St. Louis	Seldon J. King	Lynn Hartmann, 40 Rolling Hills Dr., Florissant, Mo.	3rd Tuesday—Coronado Hotel, St. Louis, Mo.
Syracuse	William Lyon	Norman C. Fesenmyer, Pennzoil Div. of South Penn Oil Co., Cortland, N.Y.	3rd Monday—Yates Hotel, Syracuse, New York
Toronto	W. Gossett	A. G. Almack, Imperial Oil Ltd., 150 Laird Drive, Toronto 17, Ont., Canada	Not reported
Twin Cities	Richard J. Eischens	Reuben C. Johnson, D. W. Onan and Sons, Inc., 2515 University Ave., So. E., Minneapolis 14, Minn.	Last Thursday—The President, 3021 Nicollet Avenue, Minneapolis, Minn.
Wheeling	Earl C. Milhorn	Samuel H. McGlumphy, c/o Paul D. Metzger, Wheeling Steel Res. Lab., Wheeling, W. Va.	1st Wednesday—Jebbia's Restaurant, Martins Ferry, Ohio
Youngstown	Edward M. Downs	.....	2nd Thursday—Mahoning Valley Country Club, Girard, Ohio

ASLE Technical Digest

Papers which, because of space limitations, cannot be published in full in Lubrication Engineering or ASLE Transactions.

"Problems Associated With the Development and Marketing of Gear Lubricants," by A. A. Manteuffel and J. B. Stucker, Pure Oil Company

A discussion of some of the problems that might be associated with the development and the marketing of automotive differential gear oils of the future has been suggested, but since many of the present day requirements have not been resolved with complete acceptance, speculation on the future problems is extremely hazardous. Therefore, we have chosen to reflect on some of today's problems from the viewpoint of the oil company marketing the lubricant.

For many years axle lubricants were considered to fall into two categories, namely, passenger car associated with high speed and truck associated with high torque. The passenger car category was further subdivided into the "factory fill" ("green gear") and the "refill" (broken-in gear) requirement.

The truck "green gear" requirements were normally expressed in load carrying capacity at relatively low speeds and torques in the range of 30,000 to 40,000 inch pounds on the ring gear. Passenger car "green gear" requirements were usually expressed in terms of satisfactory anti-score under high speed test conditions, and the test procedure appeared to be a complex function of many variables.

All these tests probably serve some purpose but may not give the answer to questions that face the marketer of gear lubricants, as for example, will it satisfactorily lubricate the differentials of trucks and passenger cars on a refill basis over a reasonable drain period?

Because of the complexity of the situation, we have come to the conclusion that the only way the durability of the gear oil can be determined is to run the lubricant in units under conditions that are met in actual service, i.e., towed loads for passenger cars and trucks, mountain truck tests and high speed mileage accumulation on turnpikes and other highways.

When it became evident that many of the automobile manufacturers were considering phosphate coating of differential gears to alleviate the "green gear" break-in problem, a study was made of the potential effect of this coating on gear lubricant requirements at the service station level.

The old General Motors Shock Test was chosen for the road testing and a Modified SAE Machine test was of most interest as a bench test. (References and description of these procedures are given in the original paper.)

G. M. Shock tests were run on a lubricant with an 8-90 level of high speed performance. This blend would not pass with "green gears" however, with phosphate coated gears a pass was obtained on a blend of the same additive at a 4-90 level of high speed performance.

The bench test work with coated test parts revealed the anticipated weight loss increase but no adverse effect on the high torque properties based upon surface appearance of the rings. When two coated rings were run against each other with a lubricant of 8-90 performance level and passing CRC L-37 Combination Test, the weight loss was high and wear continued until only slight etching remains. When only one ring was coated using the same lubricant, wear was not so great and the remaining etching marks were considerably deeper. (Photomicrographs of both gear tooth sections and Timken rings employed in these experiments are included in the full length paper.)

Based upon the work on phosphated surfaces, it was concluded that differences in grain structure and depth of surface etching were important factors when considering proper lubrication of phosphate coated gears. It was also felt that the presence of the phosphate coating would not permit a reduction in the high torque level of performance and the properties associated with high torque must certainly be considered independently.

Several questions are raised from a marketers standpoint relative to various performance level lubricants. Among these are some involving the 10-90 level 1956 Yuma test lubricant wherein some of the lubricants showed substantial additive depletion of certain anti-weld elements after 5000 miles under severe operating conditions. Does this suggest avoidance of extended drain periods or does this mean that safety factors of 2X to 3X are required to insure satisfactory overall performance for all types of gear lubricants for as short a service as 5000 miles?

(Digested by the Abstracts Sub-committee on the Gear Lubrication Technical Committee, P. A. Asseff, Chairman.)

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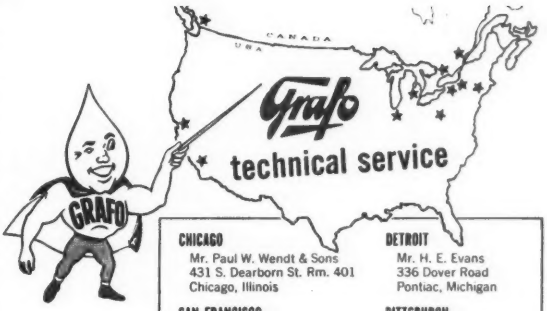

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Lubrication Abstracts

Edited by W. E. Campbell

Selected literature compiled by members of the Technical Committees and Industry Councils of the Society.

J. E. Cox (Shell Oil Co., Martinez Research Laboratory, Martinez, Calif.) P. D. Hobson, "Lubrication of Large Diesel Cylinders," *Mechanical Engineering*, Tech. Digest, v. 80, no. 7, 1958, 669.

The development of cylinder lubricating oil for large (8 to 29 in. bore), two-cycle diesel engines using heavy, high sulfur fuels (Bureau of Standard No. 6) is described. Cylinder wear caused by operating temperatures below the local dewpoint of dilute sulfuric acid and the large amount of carbon produced, especially at light load, is high with conventional high detergent oils. Fuel containing radioactive cobalt napthenate is used to determine crankcase contamination. Data for crosshead and trunk piston engines show that about the same amount of contamination exists, though in the crosshead design only about 20% as much reaches the crankcase due to the sealing gland. A suitable oil must have E.P. qualities to retain strength, dispersants to prevent deposits, detergents to remove deposits, and alkalinity to neutralize acidic combustion products. With a water soluble calcium additive oil, the water flashes off the hot piston and cylinder to "steam clean" the engine. The properties of this oil are: 1250 SSU at 100°F., 44 mg KOH/gm base no., 23% w water content, and 5.7% w sulfated ash. With this commercial oil cylinder wear rates are reduced greatly over that experienced with heavy fuels and Supp. 1, SAE 40 oil. Wear with this emulsion lubricant and heavy fuels is the same or less than when using 2D fuel and high-detergent oil, while cylinder and piston cleanliness are much improved. *(Abstractor: George C. Lawrason)*

C. Timms (Nat. Engg. Lab., E. Kilbride, Glasgow), "Recent Developments in Spur and Helical Gears," Preprint, Inst. of Production Engrs., Mar. 1960.

This paper relates largely to improvement in geometrical accuracy during the last 25 years. Fatigue tests show that allowable load depends strongly on the dimensional accuracy and this should be recognized in load rating formulas. Load capacity increases with increasing speed, contrary to the usual assumption. No correlation is noted between gear and disc tests. Gear efficiency vs. amount of oil supplied is measured on 8 DP gears of 8" center distance. Full load losses with spray lubrication are 1% including bearing friction. With a dip of ½" to 1¾" losses are 1.2% to 3.7% with oil of 60 c.s. vis. Some remarks on gear noise tests are included. 22 references. *(Abstractor: E. A. Ryder)*

By A. O. DeHart (General Motors Corporation, Warren, Michigan), "Which Bearing and Why?" ASME Paper No. 59-MD-12, 12 pages.

A handy comparison guide is presented for the selection of fluid film and rolling contact bearings. Various bearing types and bearing constructions, as well as application data, are covered. Emphasis is given to bearing types which show promise in machine tool applications. These include self-pressurized bearings and externally pressurized bearings with restrictor control. Of particular interest is a table rating 26 bearing types against 18 pertinent selection factors. *(Abstractor: Tom Osters)*

F. T. Barwell, "Friction and its Measurement," *Metallurgical Reviews* v. 4, n. 14 1959 pr. 141-77.

A review dealing with the nature of frictional contact, nature of friction, static friction, rolling friction, mechanism of boundary lubrication and test methods. 67 references. *(Abstractor: Engineering Index)*

By C. R. Adams (Boeing Airplane Co., Seattle, Washington). "The Step Bearing—A New Concept in Air Lubrication," *Product Engineering*, v. 29, no. 50, December 8, 1958, pp. 96-9.

An air bearing incorporating machined steps into the bearing design is described. These steps, located either at the ends of the bearing or at the ends of the journal, serve a dual purpose: They provide space for air below the shaft when it is stationary or about to start up; and they restrict air flow through the bearing to produce a pressure buildup that floats the shaft. Air is supplied to the clearance space between the housing and shaft through an annular groove in the housing. Step bearings are found to have several definite advantages over the conventional hydrostatic bearing using multiple orifices. They are simple to produce, can take shock better, and are less affected by changes in air supply. A set of relationships for determining important design dimensions is given. The bearing is reported to operate hydrodynamically at higher speeds with little dependence on the pressurized air supply. Some operating considerations on the use of such a bearing are presented. *(Abstractor: by H. N. Kaufman)*

GREATER RUN-IN PROTECTION EXTENDS PISTON LIFE OF CURTISS-WRIGHT ENGINES

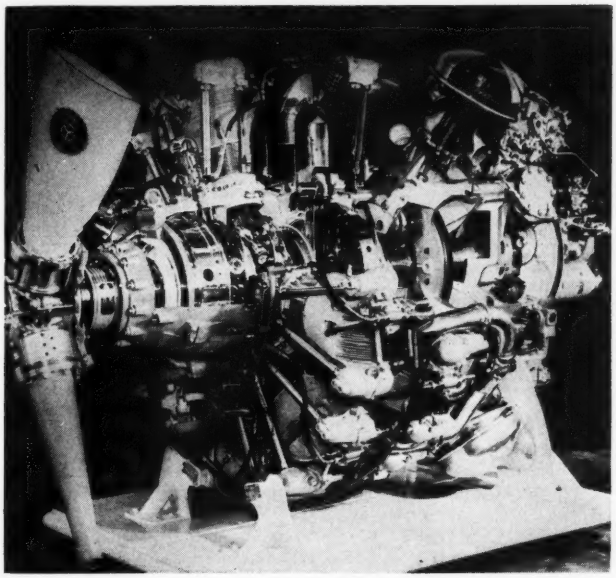

Photo courtesy of Curtiss-Wright Corp.

Curtiss-Wright Corporation's Wright Aeronautical Division, located at Wood-Ridge, N.J., has extended the "life span" of pistons used in their radial reciprocating airplane engines. By coating piston skirts with 'dag' 213 — a dispersion of graphite in an epoxy-resin binder — they are protected against scuffing, scoring, galling, and seizing during the critical running-in period.

Where previously Curtiss-Wright engineers had used finely powdered graphite and phenolic resin, they found that 'dag' 213 was more uniform in consistency and had better adhesion . . . was actually adsorbed by the surface to form a more durable, corrosion-resistant film that became virtually integral with the metal. Due to the heat-transmission properties of 'dag' 213, the coefficient of friction is kept at a uniform minimum to assure free action and proper wear-in characteristics. The exacting clearances in reciprocating engine design make the run-in process so critical that perfect friction and heat control must be maintained under the speeds and loads required. In addition, the graphoid surface takes over the job of supporting the load if the liquid lubricant ruptures momentarily during run-in, thereby preventing metal-to-metal contact until the oil film re-establishes itself.

'dag' 213 is spray-applied at Curtiss-Wright with conventional spray equipment. After the piston skirts are coated, the preassembled pistons are oven-heated at 350°F for 2½ to 3 hours. Fabrication and treatment techniques used at Curtiss-Wright permit a high degree of accuracy in maintaining piston and cylinder wall tolerances. Only forged aluminum alloys are used for these pistons which operate within nitrided steel cylinder walls. The application of Acheson's 'dag' 213 has been extended to all models of Curtiss-Wright engines in both their 18 and 9-cylinder categories. Investigate the use of an Acheson Dispersion in your own assembly or run-in application. Write Dept. LE-10.

New Literature Describes Assembly and Run-in Uses

The value of Acheson Dispersions as additives in assembly and run-in lubricants is described in easy-to-read form in a recently printed brochure, Bulletin 421. A copy for your personal file is available immediately upon request.

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6. Lessen oil consumption.
7. Shorten the period necessary for run-in.
8. Protect against momentary oil failure.
9. Lower maintenance and replacement costs.
10. Insure a longer, more trouble-free equipment operating life.

If you are concerned with the design or manufacture of engines, motors, bearing assembly, or machinery, Bulletin 421 should prove of interest to you. The vital contribution which Acheson Dispersions of colloidal graphite or molybdenum disulfide make in safeguarding against excessive wear during running-in, is a matter of record. Also, Acheson dry film lubricants, used in assembly press fit applications, are providing effective lubrication without sacrificing the tolerances involved. Send for your copy of Bulletin 421, "For Assembly and Run-in Lubrication".

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Patent Abstracts

Compiled by Ann Burchick
Aluminum Co. of America

Method of Forming Cold Extrusion Lubricants Having a Zinc Phosphate Undercoating, Patent #2,921,865 (W. L. Kubie, assignor, by mesne assignments, to aluminum Research Corp.) In a method for applying a lubricant to a metal billet prior to the cold extrusion thereof, the steps comprising: applying a uniform coating of zinc phosphate to said billet; placing the coated billet in a lubricating bath comprising an aqueous mixture of a water soluble salt of stearic acid and free stearic acid wherein the zinc phosphate coating is converted to a lubricant coating including zinc stearate; and maintaining the free stearic acid concentration of the lubricating bath at a level such that 10 ml. of the bath is neutralized by 0.6 to 0.8 ml. of 0.10 N sodium hydroxide by the addition of stearic acid.

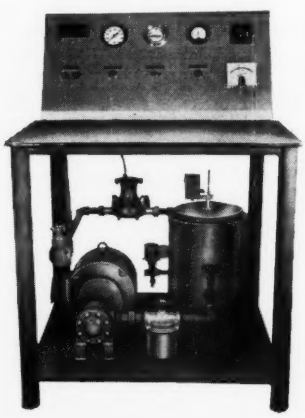
Oil Dispersions of Calcium Acetate Hydrates, Patent #2,927,892 (A. J. Morway, assignor to Esso Research & Engineering Co.) A dry lubricating composition comprising a major proportion of lubricating oil and as a sole salt component about 2 to 40 wt. % calcium acetate hydrate selected from the group consisting of calcium acetate monohydrate, calcium acetate dihydrate and mixtures thereof.

Method of Preparing Ureido Grease Thickener Concentrate and Lubricating Greases Containing Same, Patent #2,925,387 (T. Traise, W. L. Hayne, Jr., and K. R. Bunting, assignors to Standard Oil Co.) The method of preparing a concentrate of a lubricating oil containing at least 25% of a ureido compound.

Method of Using Low Viscosity-Low Volatility Mineral Oil and Wax in an Insulated Electric Cable, Patent #2,914,430 (A. King and K. J. Collins, assignors to British Insulated Callender's Cables Ltd.) In the manufacture of electric cable having a dielectric of impregnated fibrous insulating material, the method which comprises impregnating the insulating material with an impregnating compound which is a normally plastic solid and which comprises as essential ingredients micro-crystalline petroleum wax having a melting point of not less than 80C. and not less than 30% by weight of mineral oil having a viscosity of less than 30% by weight of mineral oil having a viscosity of less than 100 centistokes at 0C. and showing a loss of less than 2% when heated for 5 hours in air at approximately 110C. as specified in Method I.P. 46/51 of the Institute of Petroleum.

Insulating Oil Compositions, Patent #2,921,011 (H. Ordelt and Eva-Maria Jahn, assignors to The British Petroleum Co., Ltd.) An insulating oil composition consisting essentially of a mixture of a mineral oil and 0.1-10% by weight of a multi-constituent hydrocarbon fraction boiling over a range of temperatures between an initial boiling point and a final boiling point, the said fraction being a platformer bottoms substantially free from olefins and containing, in addition to its other constituents, at least 20% by weight of monocyclic aromatic, and having a 10% distillation point of at least 160C. and a 90% distillation point of not more than 300C.

Lubricants for Refrigerating Systems, Patent #2,926,139 (F. R. Mott and J. Pfirschke and H. Morschel, assignors to Farben fabriken Bayer Aktiengesellschaft) A composition useful in refrigeration consisting essentially of difluoromonochloromethane as a refrigerant and a polymeric liquid lubricant, said lubricant being a polyester prepared by reacting a mixture of 2 mols of butyleneglycol-1, 3 and 1 mol of ethyleneglycol with a mixture of 1 mol of adipic acid and 1 mol of succinic acid and subsequently esterifying the remaining hydroxy groups with butyric acid.



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LUBE IN THE NEWS

(*Continued from page* 445)

26 MILLION DOLLAR EXPANSION PROGRAM PLANNED FOR ARCHER-DANIELS-MIDLAND COMPANY

Archer-Daniels-Midland Company has announced the earmarking of 26 million dollars for investment in new plants, products and equipment in the next two years.

Eighty per cent of the planned 26 million dollar spending for capital improvements, will go for new plants and new products, according to the ADM president, and to expand production and increase efficiency in the company's more than 100 plants, elevators and mines located throughout the United States.

A major item in the ADM plan is the construction of a new multimillion dollar chemical center at Peoria, Illinois. The plant is scheduled for completion in 1962.

ADM is linked with agriculture, since many of its chemicals are derived from vegetable oils. The company's expansion program includes the improving of processing facilities, storage and merchandising installations. (Source: Archer-Daniels-Midland Co.)

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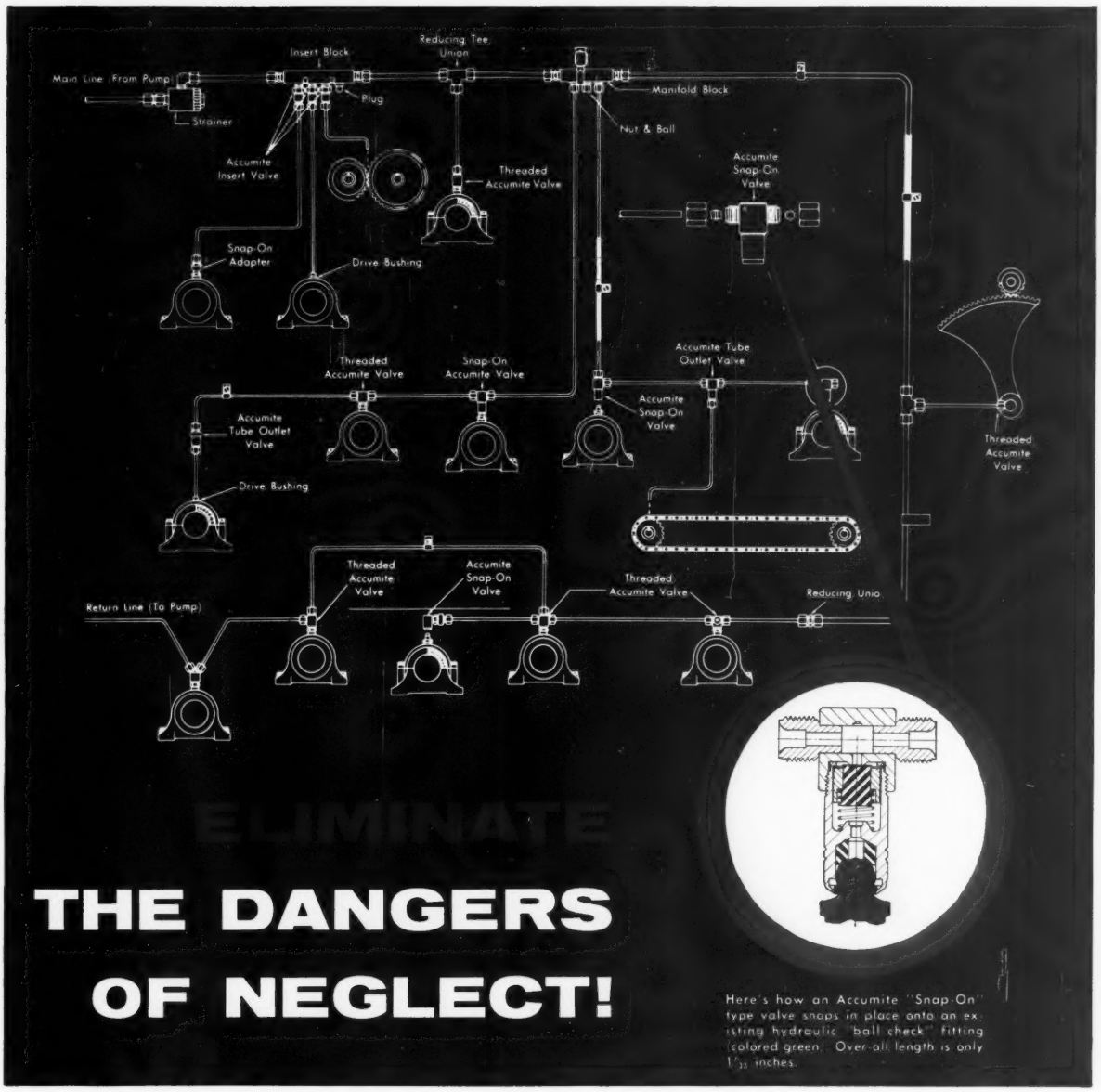

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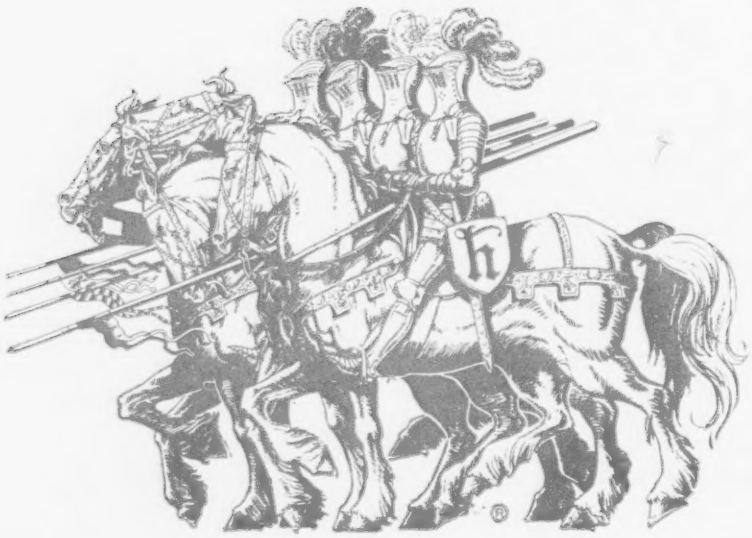

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